SANTA CRUZ LABORATORY
PROGRAM REVIEW 2004
September 29, 2004

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
Santa Cruz Laboratory
110 Shaffer Road
Santa Cruz, CA 95060

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September 29, 2004

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..... Alec MacCall

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***Salmon Population Analysis Team* .....1015 - 1200**
..... Pete Adams
..... Eric Bjorkstedt
..... Chris Donohoe
..... Steve Lindley
..... Michael Mohr
***Fisheries Economics Team*.....**CindyThomson

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***Salmon Ocean Ecology Team*.....**Bruce MacFarlane
***Molecular Ecology Team*.....**Carlos Garza
***Habitat Ecology Team* .....**Tom Laidig
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Comments from the Science Director**.....1600 - 1630**

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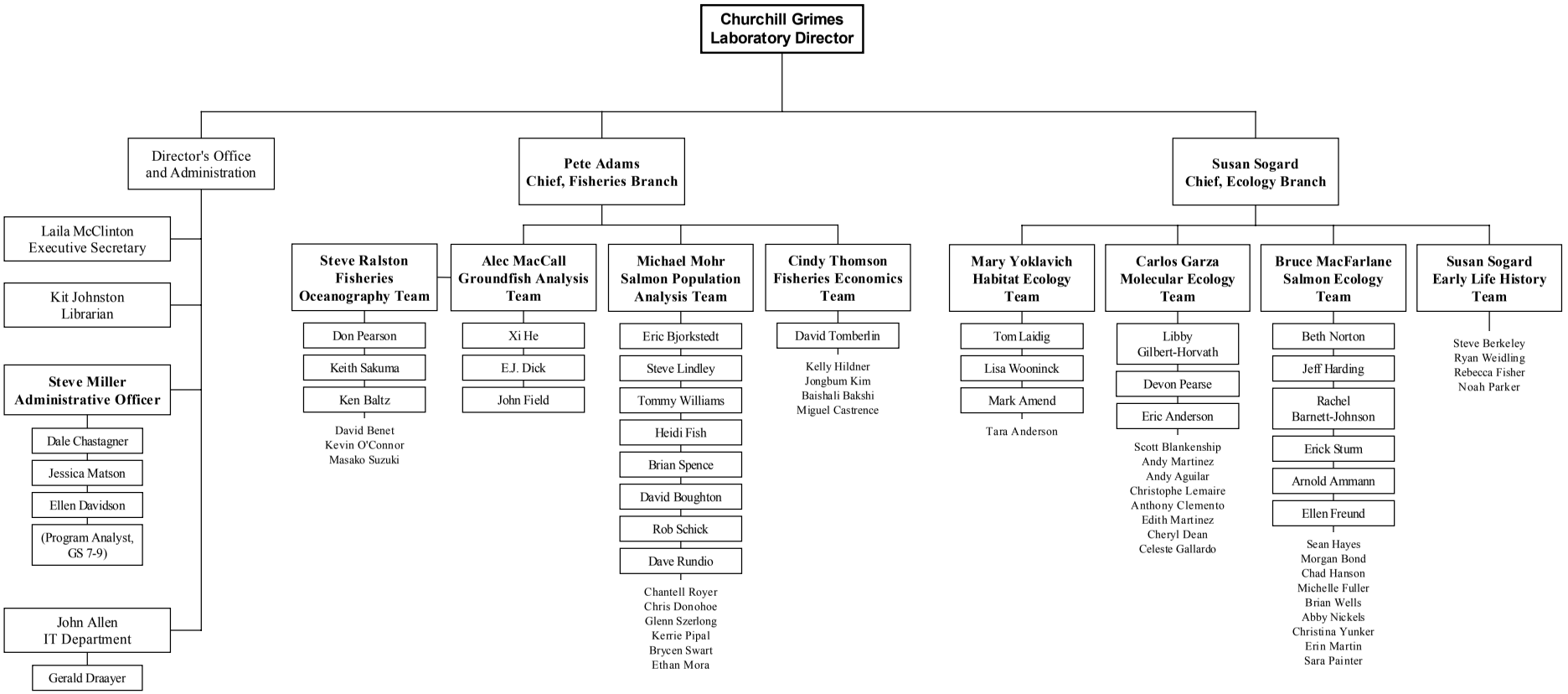
ADJOURN 1730

National Marine Fisheries Service
Santa Cruz Laboratory



Last updated August 2004

OVERVIEW OF THE SANTA CRUZ LABORATORY OF THE SOUTHWEST FISHERY SCIENCE CENTER

Organization

The National Marine Fisheries Service (NMFS) is a division of the National Oceanic and Atmospheric Administration (NOAA), which resides in the United States Department of Commerce. NMFS can be referred to as NOAA Fisheries. The field operations in NMFS are divided into 5 geographic regions. The southwestern U.S. falls within the jurisdiction of the Southwest Region (SWR), headquartered in Long Beach, California and the Southwest Fishery Science Center (SWFSC) located in La Jolla, California.

The Santa Cruz Laboratory (SCL) is one of three laboratories comprising the SWFSC. In addition to La Jolla and Santa Cruz, the other laboratory is located in Pacific Grove, California. The Director of the Santa Cruz Laboratory, Dr. Churchill B. Grimes, reports to Dr. William W. Fox, Science Director of the SWFSC, through his deputy Dr. Norman Bartoo.

The SCL is divided into two research branches: Fisheries and Ecology. The Fisheries Branch, led by Dr. Peter B. Adams, is made up of four teams: Salmon Population Analysis, Economics, Groundfish Analysis and Fishery Oceanography Analysis. The Ecology Branch, led by Dr. Susan Sogard, is comprised of four teams: Early Life History, Salmon Ocean and Estuarine Ecology, Habitat Ecology and Molecular Ecology. The complete organizational structure of the SCL, including administrative structure and staffing as well as research team leadership and staffing are given in the included organizational chart.

Research Program

The research program of the Santa Cruz Laboratory is focused in two primary areas: 1) biological and economics research supporting the restoration and recovery of threatened and endangered salmonid fishes in California (pursuant to NMFS responsibilities under the US Endangered Species Act), e.g., distribution and abundance, metapopulation dynamics and viability analysis, population genetics, life history tactics and strategies, spatial ecology, wild v hatchery interactions, ocean and estuarine ecology; and 2) the biological and economic basis of rational management of west coast groundfish resources, e.g., life history, population dynamics and stock assessment, recruitment dynamics and fishery oceanography, habitat ecology and marine protected areas and recreational fishery resource economics.

Partnerships

Cooperative relationships with other organizations assist the laboratory in accomplishing the research mission. The laboratory houses the National Marine Protected Area Center Science Institute (NMPAC-SI). Created by a Presidential Executive Order in 2000, the NMPAC is a partnership between two NOAA agencies, NMFS and the National Ocean Service (NOS). The NMPAC supports research relevant to siting, evaluation and implementation of MPAs for conservation and management of a variety of cultural and biological resources. The principal academic partner of the laboratory is the University of California at Santa Cruz (UCSC) with whom laboratory scientists conduct many collaborative research projects, and participate in graduate academic programs through courtesy faculty appointments. The Center for Stock

Assessment Research (CSTAR) is a special feature of the partnership with UCSC. Other research partners include United States Geological Survey, NMFS Northwest Fishery Science Center, the University of California at Santa Barbara, Moss Landing Marine Laboratories, Humboldt State University, California State University Monterey Bay, Duke University, Washington State University, Oregon State University, California Department of Fish and Game and the Monterey Bay Salmon and Trout Project.

Facility

The SCL replaced obsolete facilities at Tiburon, California. The new state of the art 53,400 square foot facility was occupied in December 2000. Constructed at a cost of approximately $20 million, the facility includes: office accommodations for approximately 65 administrative and scientific staff; ultramodern biological and chemical laboratories that support cutting-edge analytical approaches, e.g., in biochemical genetics and otolith micro structural and micro chemical analysis; latest information technology infrastructure, e.g., copper, fiber-optic and coaxial cable drops in nearly every work space, LAN of latest PC and workstation platforms and peripherals to support computationally intense modeling analyses, connectivity to University of California system-wide networked assets such as on-line journals; environmentally friendly design; experimental seawater and freshwater aquarium systems with digital control of environmental conditions and an exterior captive broodstock facility where large volume experiments can be conducted; digital and motion sensor control of the environment in all interior spaces; digital imagery laboratory for analysis of *in situ* video, acoustic and electro-optic imagery for seafloor mapping and GIS georeferencing and layering.

Approximately $2.5 million worth of improvements to the facility have been completed by the summer of 2003 including: carpeting of all common areas; addition of 8 offices, 15 office cubicles and 2 dry laboratories; improved landscaping; additional parking; completion of the seawater system and construction of a captive broodstock facility.

Staffing

There are about 55-60 total staff members, including 44 permanent federal FTE (5 administrative, 2 information technology and the balance scientific) and 15-20 temporary scientific support staff. The expertise of the staff is mainly fishery biology, ecology and mathematical modeling (population dynamics, stock assessment and extinction risk modeling, genetics and molecular ecology, fishery oceanography and ecology, physiology and behavior), but also includes resource economics. Approximately one-half of the scientific staff holds Ph. D. degrees.

FISHERIES BRANCH

The Fisheries Branch brings together the management-related tasks within the Santa Cruz Laboratory, and due of this, is heavily oriented toward quantitative population ecology and quantitative economics. The Branch consists of the Groundfish Analysis and Fishery Oceanography Team, Salmon Population Analysis Team, and the Fisheries Economic Team. The Groundfish Analysis and Salmon Population Analysis Teams' orientation towards quantitative population ecology also carries over into basic research into the underlying biological mechanisms and environmental conditions that control the population dynamics of the fishes under consideration. Likewise, the Fisheries Economic Team conducts basic research to explain the underlying economic structure of these fisheries and to predict their behavior. These investigations are not only directed at basic research, but also fill critical information needs for NOAA Fisheries managerial responsibilities. The Branch is heavily involved with NOAA Fisheries' responsibilities with the Endangered Species Act (ESA) and the Pacific Fisheries Management Council (PFMC).

Salmon Population Analysis Team

Introduction

The Salmon Population Analysis Team (SPAT) conducts research relevant to the conservation and restoration of anadromous salmonids, with an emphasis on population dynamics and related aspects of community and landscape ecology. The Team focuses on problems particular to California, which is at the southern end of the range for the focal species. SPAT's research interests and expertise cover four broad areas, including conservation biology, population ecology, spatial ecology, and these lead to the development and application of quantitative methods (Figure 1). Team members may typically engage in any or all of these areas. This integrated approach provides the Team with broad capabilities for bringing science to bear on applied ecological problems.

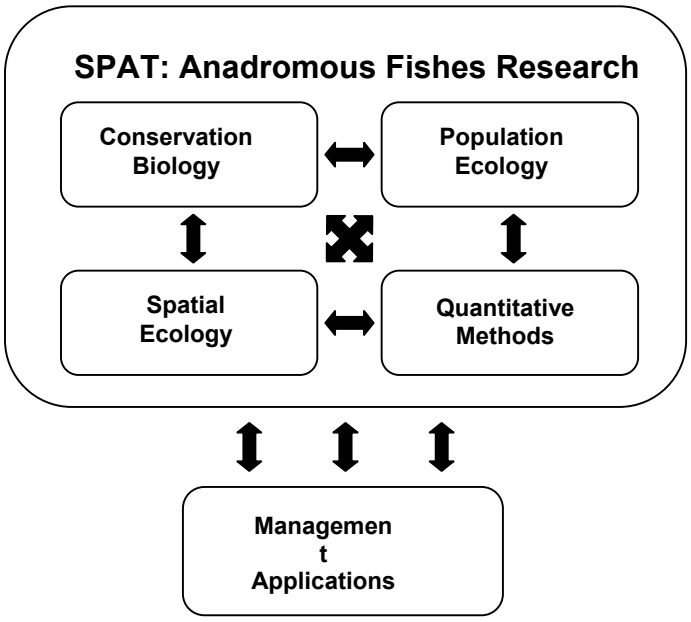


Figure 1 Schematic of the Salmon Population Analysis Team's (SPAT's) research activities and relation to management needs.

The Team's research and service activities are closely related to NOAA Fisheries management responsibilities under the Endangered Species Act (ESA) and the Sustainable Fisheries Act (SFA). Indeed, the formation of SPAT traces back to the rising need for scientific expertise related to population biology of California's anadromous salmonids in the mid 1990s.

At that time, NOAA Fisheries (with the assistance of several SPAT members) began systematic, coast wide status reviews of 7 species of Pacific salmon and anadromous trout. The status reviews resulted in the identification of 57 evolutionarily significant units (ESUs), 27 of which were subsequently listed as threatened or endangered under the ESA. Effective management of these ESUs requires significant scientific input, and SPAT provides most of this input for the SWFSC.

Team members provide scientific input to resource management by focusing a broad range of quantitative and field-oriented expertise and experience 1) to fulfill requirements for immediate analysis, and 2) to identify and attack scientific questions that address issues critical to improving ongoing and future management. Scientific service in support of management has, to date, dominated the Team's time and resources. These activities include 1) participating on numerous ESA Biological Review Teams to assess the conservation status of anadromous fish throughout California and the Pacific Northwest, 2) leading and serving on four ESA Technical Recovery Teams to develop the scientific underpinnings of recovery plans for listed ESUs throughout California and coastal Oregon, 3) providing analytical support and serving as technical advisors to the Pacific and Klamath Fishery Management Councils, and 4) working within NOAA Fisheries and with sister agencies to ensure consistency and rigor in management-oriented science.

Our service activities have inspired new research questions that broaden our scientific understanding of the life history and population dynamics of anadromous salmonids while having direct relevance to present and future management issues; these topics are described in some detail below under **Research Activities**. However, we have been required to commit substantial time and energy in direct support of resource management; these activities are reviewed below under **Management Support Activities**. We follow with a brief list of **Accomplishments** achieved since 2002, and then finish the review with a discussion of **Future Research Directions** that address existing and emerging problems in the management of anadromous fishes in California.

Within the Team's broad focus on population dynamics, there is significant feedback among four major areas (conservation biology, population ecology, spatial ecology, and quantitative methods) with needs or developments in one area driving progress in others. The linkage to management application is also significant—some research projects are a direct response to pressing management problems, while others are intended to improve future management capacity by developing information and approaches that managers do not yet know they need.

Objectives

The goal of the Salmon Population Analysis Team is to conduct basic ecological, evolutionary, and methodological research relevant to the conservation and restoration of anadromous salmonids, and to contribute scientific support to anadromous salmonid ESA and SFA management activities. Specific objectives are:

- Collect or coordinate the collection of distribution and abundance data critically needed for population assessments;

- Devise statistically robust survey methods and population estimators for use in research and management;
- Investigate key life-history characteristics and their role in population dynamics;
- Develop methods for modeling population viability and metapopulation dynamics;
- Provide scientific support for ESA and SFA management activities, and expertise to the SWR and other groups as appropriate.

Research and Management Support Activities

Conservation Biology

Much of our research is directly relevant to management of threatened and endangered salmonids. Most of this research is related to technical recovery planning; other work supports more general conservation efforts (e.g., *An Ecosystem Approach to Salmonid Conservation*), while still other work is in response to specific management problems.

Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units

In preparation for technical recovery planning, we collaborated with colleagues at the Northwest Fisheries Science Center to develop a conceptual framework for assessing ESU viability and predicting the characteristics of an ESU consistent with a negligible risk of extinction (McElhany et al. 2000). To do so, we synthesized a broad literature spanning conservation biology, ecological and evolutionary theory, and salmon biology. The framework that emerged from this effort focuses at the level of the population, explicitly recognizes the contribution of biological structure and variability within the ESU to viability of the ESU, and develops principles for assessing the viability of individual populations and integrating the status, distribution and diversity of populations to consider viability at the scale of entire ESUs. The core of this framework has provided a strong foundation for the activities of the Technical Recovery Teams and recent Biological Review Teams, yet has accommodated continued evolution of thinking on the conservation biology of anadromous fishes. In both informal and formal arenas, SPAT members have played a critical role in the ongoing development of these concepts and their application over the broad ecological range of anadromous salmon and trout.

Population Viability Assessments

We have been active in developing and applying methods for assessing the viability of salmonids populations. Lindley and Mohr (2003) studied the effect of striped bass stocking on the viability of winter-run chinook salmon with a Bayesian population viability analysis that explicitly included predator-prey interactions. This study showed that a proposed striped-bass stocking program could pose a significant additional risk to winter-run chinook salmon, which face a fairly high risk of extinction even in the absence of predation by striped bass. These results were influential in reducing the scope of the striped bass program. We developed a new method for analyzing population time series that contain significant observation error (Lindley, 2003); this method is being applied in viability assessments for status reviews (e.g., Lindley, 2003) and technical recovery planning (Lindley, et al., in prep). In cases where data are insufficient for even simple time series modeling, we are developing a "rules of thumb" approach for assessing viability, based on effective population size, trend in abundance, occurrence of recent catastrophes, and the degree of hatchery influence (Lindley, et al., in prep). This approach will allow viability criteria to be set for the many populations of salmon and steelhead for which we have little or no data.

Identification of Historical Population Structure of Salmonid ESUs

We are bringing a variety of techniques to bear on the question of historical population structure of threatened and endangered salmonid ESUs in California and coastal Oregon. Historical population structure provides a critical context for recovery planning by establishing a baseline for which we can be most certain that an ESU was at negligible risk of extinction. Against this template, we compare current and possible future population structures, under the assumption that increasing deviation from historical conditions requires stronger demonstration that a particular structure yields a viable ESU.

We are using a suite of approaches to estimate historical population structure in listed ESUs. Two approaches–collaborative investigation of population genetic structure (see *Molecular Ecology Team – Research and Management Support Activities: Population genetic structure*), and analysis of correlations in time series of spawner abundance in a state-space modeling framework (see *Research Activities – Quantitative Methods: State-Space Models*)–are discussed in more detail elsewhere. Two other methods are rooted in analysis of geographic information, and are supported by an in-house GIS. In both cases, we are examining the spatial distribution of spawning areas as a key determinant of reproductive isolation.

The first analysis uses various measures of population connectivity to examine ESU structure. We identify demographic units for subsequent consideration by applying a biological rule to define discrete populations based on the distribution of spawning habitat. For example, saltwater entry is used to separate populations in coastal ESUs, while ecologically relevant isopleths (e.g., 500 m elevation for spring-run Chinook, or 24°C isotherm for steelhead) are used to partition watersheds occupied by putative populations in Central Valley ESUs. Since we lack suitable biological data, we derive proxy measures for relative abundance from geomorphic and hydrologic information in GIS (e.g., see *Research Activities – Spatial Ecology: Intrinsic Potential of Watersheds to Provide Salmonid Habitat*). We use GIS to estimate network distances among populations, and calculate dispersal rates either as a simple function of distance (for quasi-linear cases, such as coastal watersheds that drain directly to the Pacific Ocean), or as a function of watershed structure (e.g., number of chances to make a wrong turn within a system such as the Sacramento-San Joaquin system of the Central Valley). We combine proxy values for relative population size and dispersal rates into a simple expression for self-recruitment to a population, which is defined as the proportion of the spawning run returning to a population that was born in that population (Figure 2).

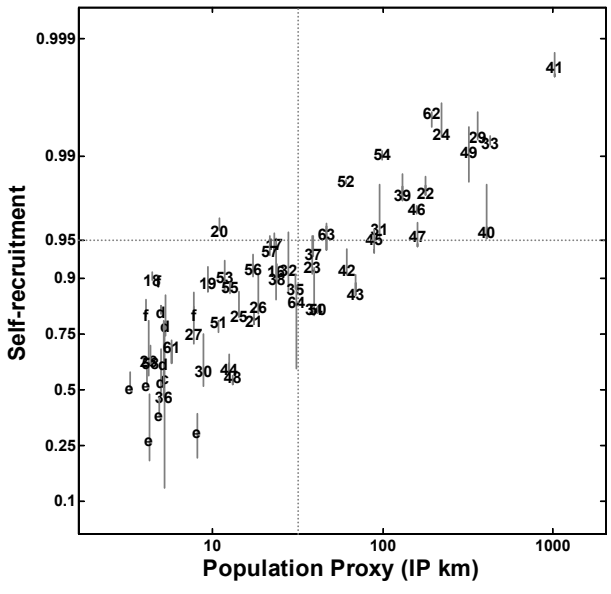


Figure 2 Relative population size and self-recruitment to coho salmon populations in the Central California Coast Coho Salmon ESU.

We use these results to classify populations according to their potential to be viable-in-isolation (i.e., to have negligible risk of extinction over 100-year time frames even in the absence of immigration subsidies) as a function of potential population size, and their degree of self-recruitment, which provides a measure of how "closed" or demographically independent a population is. Since the latter distinction is difficult to quantify, we compare self-recruitment to fidelity rate as a measure of whether a population is a "source" or a "sink." Populations are classified into: 1) Functionally Independent Populations, which are viable-in-isolation and, as indicated by self-recruitment in excess of fidelity, are expected to have strongly independent internal dynamics; 2) Potentially Independent Populations, which are sufficiently large to be viable-in-isolation, but receive sufficient immigration to influence their internal dynamics; 3) Dependent Populations, which are too small to be viable-in-isolation, but receive sufficient immigration subsidy to persist so long as the source population(s) are extant; and 4) Ephemeral Populations, which are too small to be viable-in-isolation, but are too isolated to receive sufficient immigration to support persistence and so are expected to be occupied rarely and for relatively short periods.

The results of this analysis illustrate the strong relation between population size and self-recruitment (Figure 2) and allow us to incorporate the spatial context of a population in analyses of population independence and connectivity in historic and current contexts. These data will also be analyzed with graph theoretical approaches to examine how ESU structure changes as thresholds for effective connectivity vary (see *Research Activities – Quantitative Methods: Graph Theory*).

In the second analysis, we use ordination analyses (Figure 3) to discern environmental differences between or within watersheds that might underlie differences in selective regime and drive local adaptation. Such differences provide useful information for discerning population structure, particularly divisions within major watersheds. Environmental differences also support analysis of structure between the scales of the population and the ESU and elucidation of the distribution of potential diversity within the ESU, both of which are relevant to ESU viability.

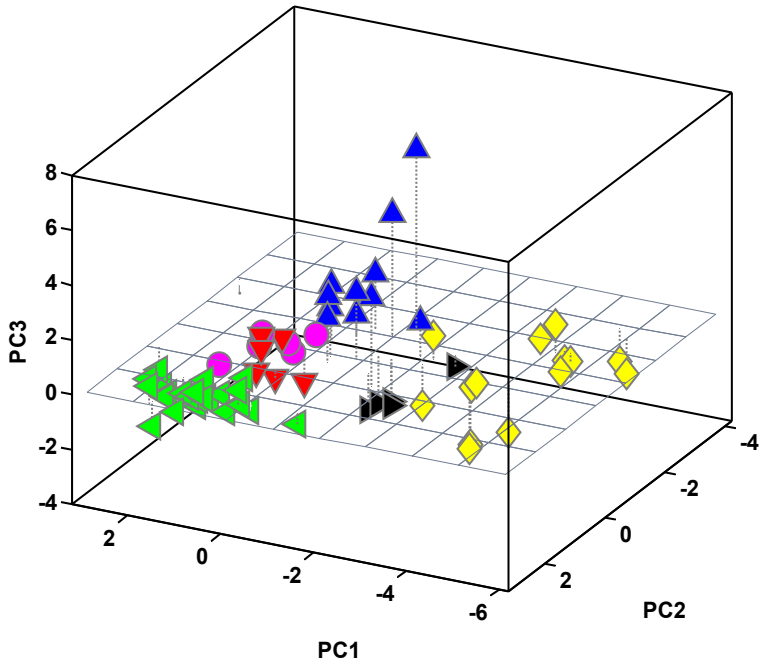


Figure 3 Principle components ordination of coastal watersheds in northern California based on physical habitat attributes. Colors indicate diversity units identified by the North-Central California Coast TRT, and include consideration of spatial information.

An Ecosystem Approach to Salmonid Conservation

In 1995, NOAA Fisheries, the U.S. Fish and Wildlife Service, and the Environmental Protection Agency oversaw development of a coordinated, region-wide strategy for developing, evaluating, and monitoring Habitat Conservation Plans (HCPs) prepared pursuant to the ESA; for fostering habitat protection and conservation on nonfederal lands beyond minimum ESA requirements and consistent with the mandate of the Clean Water Act; and for providing education and training in habitat protection and restoration strategies. The result of this effort was publication of "An Ecosystem Approach to Salmonid Conservation," (Spence et al., 1996), which has since guided conservation planning and evaluation of HCPs. A second edition of this document, "Resisting Extinction: An Ecosystem Approach to Salmonid Conservation", is currently being prepared by Team scientists. The revised edition incorporates scientific advances since 1995 and updates recommendations regarding development, evaluation, and monitoring of conservation activities based on practical experiences from ongoing efforts in the Pacific Northwest. Resisting Extinction comprises three parts. Part I describes the linkages between salmonids and their physical, chemical, and biological environment with an emphasis on watershed processes. Part II reviews the effects of human activities—including forestry, livestock grazing, agriculture, mining, urbanization, dams, water diversions, hatcheries, and harvest—on salmonids and their habitat. Part III proposes a strategy for conserving salmonid habitats in the Pacific Northwest and California, with an emphasis on nonfederal lands. We identify key issues relevant to conservation at the regional, watershed, and site levels, and recommend appropriate analyses and prescriptions for protecting salmonid habitats. *Resisting Extinction* will be published by the American Fisheries Society in 2005.

Geographic Variation in Genetic and Meristic Characters of Coastal Cutthroat Trout

This research was part of the completion of a doctoral research project begun at Oregon State University to examine geographic variation in genetic and meristic characters of coastal cutthroat trout (*Oncorhynchus clarki clarki*), and lays a conceptual framework for understanding how habitat variability influences the spatial distribution and persistence of populations at various spatial and temporal scales. This work, based on samples from 55 populations distributed from northern California to Prince William Sound, Alaska, represents the first range-wide description of the meristic and genetic variation in the sub-species.

Coastal cutthroat trout exhibited significant variation of meristic characters and allele frequencies across their range. Meristic characters did not reveal a latitudinal cline yet provided insight to population structure at large spatial scales. Analysis of genetic data revealed geographic concordance of populations at the northern and southern extent of the subspecies range, and demonstrated isolation-by-distance at regional scales (< 800 km) (Figure 4). The primary structure of coastal cutthroat trout populations occurred at the individual stream level, and there was genetic affinity among populations at a regional scale. These results suggest that coastal cutthroat trout exist in smaller, more genetically differentiated local populations than do other species of Pacific salmon and trout. Thus, coastal cutthroat trout may provide a useful model for examining how small populations persist in dynamic environments.

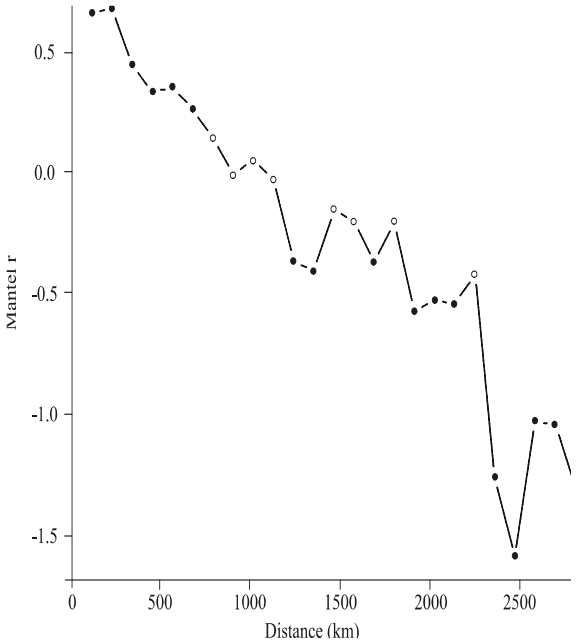


Figure 4 Correlogram illustrating correspondence between genetic distance and geographic distance among 55 coastal cutthroat trout populations.

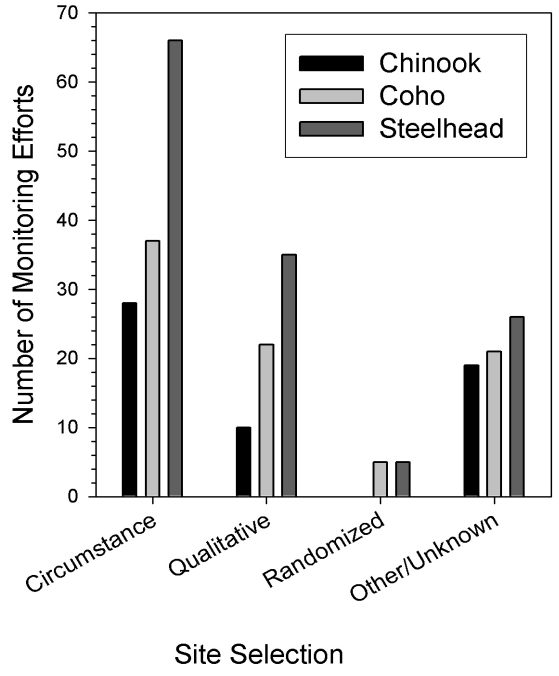


Figure 5 Methods reported by correspondents for selecting the specific sites at which they set up monitoring efforts.

Metadata on efforts to monitor salmonids in California

The team is currently engaged in several collaborative efforts to develop monitoring plans for salmon and steelhead in the state of California (see, e.g., *Management Support Activities: Coastal Monitoring Plan*). The principle goal of these collaborative efforts is to develop monitoring programs that are truly regional in scale—in other words, that allow inference about the risk status of entire ESUs rather than supporting risk assessments solely at the scale of specific populations or watersheds within an ESU. To support this planning effort, the team has prepared two comprehensive reports on existing monitoring efforts within the freshwaters of the state of California. One report focuses on efforts to monitor salmonids in the Central Valley (including the southern Cascades, Sierra Nevada, and other drainages to the Central Valley); the other report covers the coastal region between the Oregon and Mexican borders (all coastal drainages including drainages to San Francisco and San Pablo Bays). Metadata was collected systematically for the regions using a combination of literature search and phone interviews; the information reported by correspondents was categorized according to methods, sampling design, geographic scale, goals, and so forth; and then summarized to give an overview of the metadata (Figure 5). These reports are the first comprehensive effort to describe the diverse set of monitoring activities statewide.

Population Ecology

The origin of SPAT, as indicated by the name, was in studies aimed at the population level. While we have expanded our interests to include larger scales, population-level studies are still a major focus, including studies that examine how individual variability is integrated into population dynamics.

Life Cycle Studies of Coastal Salmonids

Californian populations of *Oncorhynchus* are known to be highly variable in size, but the underlying mechanisms of this variation—climatic, human, ecological—and their timescales are unclear. None of these questions can be addressed without detailed datasets describing the population structure of salmon populations over a long period of time. No such datasets exist for coastal California. To begin to alleviate this problem, the Team has recently initiated long-term studies of the South Fork of the Noyo River (Mendocino County) in close collaboration with California Department of Fish and Game biologists. We hope to initiate a replicate study in a southern California system. (A study focused on the role of habitat quality on salmon populations contributes a similar dataset, but is discussed in more detail below; see *Research Activities – Population Ecology: Survival of Coho Salmon in Habitats of Varying Quality*).

The specific objective of each study is to estimate annually the abundance of each life stage (adult, summer juvenile, downstream migrant) of each local *Oncorhynchus* species (coho and steelhead in the north, steelhead only in the south). Such data collection efforts require significant resources maintained over the long term, and, in general, are most appropriately conducted by government science agencies; our involvement arises from an acute need to initiate the collection of such data and a more chronic need to develop, demonstrate, and implement rigorous methods in collaboration with colleagues in state resource agencies as a way to support the development of effective monitoring programs. Over the short term, these data will be used to estimate trends in abundance, demographic parameters such as freshwater or marine survival, timing and distribution of spawning and rearing, and spawner stray rates. Over the long term it should be possible to study patterns of variability in each of these metrics.

In the South Fork Noyo River, we have collected abundance data on coho salmon (juvenile, smolt, and adult) and steelhead (juvenile and smolt) for the past four years. Abundance data on adult salmon and steelhead are collected during periodic (usually weekly) surveys of the entire spawning habitat, where we count spawners, count and measure redds, and recover salmon carcasses for mark and recapture. An advantage of our work on the Noyo River is that, at least for adult coho salmon, these abundance estimates can be compared directly against census counts taken at an exclusionary weir. In 2003–2004, we also implemented a mark-recapture study on immigrating adult salmon in order to estimate longevity of adults after entering the South Fork and estimate rates of visual detection during surveys. The data on longevity and detection are being used to improve count-based methods of abundance estimation (see *Research Activities – Quantitative Methods: Estimation of Juvenile Abundance in Small Streams*).

Summer juvenile counts and habitat data are collected using single-pass snorkeling throughout the watershed, and smolts are caught in stationary traps during the downstream migration. Results after four years of data collection indicate high variability in juvenile number as well as interesting spatial and temporal patterns of abundance. Basin-wide, young-of-the-year steelhead and coho salmon have varied by a factor of 2–4 over the four years of study, but the two species have exhibited different patterns, with coho salmon tending to be more abundant in years of low steelhead abundance and vice-versa. For both species, certain reaches in the South Fork Noyo watershed appear to consistently produce a disproportionate share of the total

juvenile population, while other reaches show much greater interannual variability, perhaps reflecting differential responses to variation in stream flows or other environmental factors.

Survival of Coho Salmon in Habitats of Varying Quality

Since 1998, we have been collaborating with researchers at Humboldt State University on a long-term project designed to examine how habitat characteristics, particularly those associated with disturbance, affect survival of coho salmon during the freshwater phase of the life history in northern California streams. In 1999 and 2000, we expanded the scope of the sampling to include adult spawner surveys for Chinook salmon and steelhead. Currently, we are near the end of the sixth full year of sampling, and have collected information on abundance and distribution of spawners, redds, juveniles, and downstream migrants in a set of connected streams, one of which flows through pristine old-growth forest, and two of which have experienced recent disturbances such as logging or landslides.

These data have provided unique insights to the ecology of coho salmon in northern California, including 1) factors and mechanisms influencing fry production from redds in habitats of different quality, 2) variation in the growth and survival of juvenile coho salmon in low-velocity overwintering habitats, and 3) the existence and prevalence of a life-history variant that spends a second winter in freshwater, which had not previously been observed in California. This work has also contributed to our understanding of the structure and productivity of invertebrate assemblages in these streams; this information is being integrated in continued work on the energetics of coho salmon in these streams. These studies will support inquiries regarding the causal mechanisms and viability consequences of the two-winter life-history variant. In addition, these data represent a short, but important time series of observations, that has allowed us to observe the consequences of environmental variability, such as interannual variation in the timing and amount of precipitation, for population dynamics and distribution. These data have also supported work on sampling designs for estimating juvenile abundance (see *Research Activities – Quantitative Methods: Estimation of Juvenile Abundance in Small Streams*), efforts to improve estimates of redd abundance through discriminant analysis of redd characteristics (see *Research Activities – Quantitative Methods: Estimation of Adult Abundance*), and analysis of density-dependence in juvenile distributions among habitats, which has implications for the use of non-abundance surveys to detect population trends (see *Research Activities – Spatial Ecology: Density-dependent Habitat Use by Juvenile Coho Salmon*).

Relationships Between Anadromous and Resident Forms of Rainbow Trout

Unlike most salmon, rainbow trout (*Oncorhynchus mykiss)* exhibit both non-migratory (resident) and anadromous (steelhead) life history forms. This life history diversity may be important in the establishment and persistence of populations of *O. mykiss* in southern California, where freshwater habitats and their connectivity to the ocean are more ephemeral than in regions to the north. Identifying the roles of the two life-history forms has been difficult, in part because juveniles of the two forms co-occur and look identical.

We are using strontium-to-calcium (Sr/Ca) ratios in otoliths to discriminate among progeny of resident and anadromous females, reconstruct the migratory histories of adults, and assess the degree of reproductive isolation between the two forms (Figure 6). To date, we have developed an extensive reference dataset on otolith Sr/Ca ratios for California using juvenile *O. mykiss* from 14 hatcheries, and applied these results to interpret patterns in otoliths of adults from 9 northern California rivers. Preliminary results show that at sites near ocean, all adults are anadromous, with 3-8% having resident mothers. At sites distant from ocean, adults may be either anadromous or resident, with up to 30% adopting the alternate life history form of the mother. These results suggest that life history "switching" varies among locations and distance from the sea, which may have important implications for evaluating population viability and connectivity among and within populations.

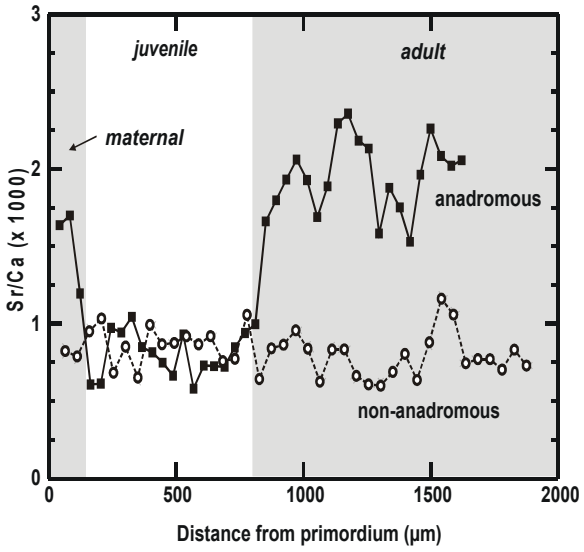


Figure 6 Cross-otolith patterns in Sr/Ca ratios of two adult *O. mykiss*. Sr/Ca ratios in the maternal region are higher in the progeny of anadromous females.

Two related studies seek to 1) quantify basin-wide variation in the contribution of resident females to natural anadromous populations in a large river system (Klamath River) using otolith, genetic, and meristic analyses, and 2) develop non-lethal alternatives to the otolith-based method using fin clips or scales which will allow research in threatened and endangered ESUs in the south. We expect the results to provide important tools and guidance in recovery planning by clarifying the role of resident fish in population viability, population spatial structure, and diversity.

The Ecology of Steelhead Trout in Coastal Ecosystems

Exchanges of nutrients and organisms between adjacent food webs are common and can have important effects on the structure and function of the constituent communities. Recent research has revealed that many aspects of the ecology of stream salmonids are influenced by subsidies of terrestrial insects. For example, in some temperate streams, terrestrial insects contribute to more than half the annual energy budgets of stream salmonids and determine the local distribution and abundance of fish. Furthermore, the seasonal pattern of these subsidies with respect to *in situ* production may affect the stability of food webs and population dynamics, and the strength of top-down effects of fish predation on stream communities may vary seasonally and in inverse proportion to terrestrial subsidies. We have initiated a long-term study of food web interactions involving steelhead trout (*Oncorhynchus mykiss*) in small coastal basins in central California to investigate the importance of terrestrial subsidies to trout in these systems, which differ in climate and vegetation from streams that have been studied previously. We are focusing initially on determining the magnitude and seasonal pattern of terrestrial subsidies relative to *in situ* aquatic prey in two streams on the Big Sur coast, and estimating the contributions of terrestrial and aquatic prey to the annual energy budget of juvenile steelhead.

We also have started experiments to determine the top-down effects of trout predation on algal and detrital food webs in these streams, and how these effects may be mediated by environmental conditions and traits of intermediate consumers. In the long-term, we are interested in expanding our study to determine the relationships between terrestrial subsidies and steelhead population dynamics (e.g., distribution, abundance, growth, life-history, and movement), and to address the broader ecosystem effects of reciprocal subsidies between stream and riparian food webs.

Spatial Ecology

Anadromous fish exhibit complex life cycles that play out across the land- and seascape. To restore, manage and monitor these fish effectively, we must understand the spatial structure of populations and ESUs, how this structure reflects and responds to dynamic processes in the physical and biological environment, how this structure filters the environment to yield the dynamics of anadromous populations, and how this structure will respond to various aspects of global change.

Intrinsic Potential of Watersheds to Provide Salmonid Habitat

We are interested in the historical distribution and abundance of salmonids, partly because this provides one measure against which current and future conditions can be assessed. Such information is generally lacking in California. A promising approach for increasing our understanding of historical distribution is through estimation of intrinsic habitat potential. "Intrinsic potential" is a measure of habitat suitability based on geomorphic and hydrologic characteristics of a watershed. In collaboration with researchers at the U.S. Forest Service Pacific Northwest Research Station, we are adapting a model originally developed to predict distributions of coho salmon and steelhead in coastal watersheds of the Coast Range of Oregon, and using it to predict intrinsic potential habitat of the same species in southern Oregon, the California coastal region, and California's Central Valley (steelhead).

Intrinsic potential of individual stream reaches is defined to be a function of the combined influence of stream gradient, valley constraint, and discharge. The underlying model uses a "fuzzy logic" model to translate habitat characteristics into a measure of suitability for a particular species. Adapting this model to southern Oregon and the California coast has entailed 1) estimating a discharge-precipitation-catchment area relation for watersheds in southern Oregon and California, 2) conducting a literature review to evaluate the suitability curves based on observations from Oregon to map habitat characteristics to habitat suitability in California and to modify these curves as needed, 3) developing and evaluating a method for interpolating a comprehensive 10 m resolution digital elevation model (DEM) from the available 30 m resolution DEM, and 4) developing additional environment-suitability relations (e.g., summer temperature) to examine the effects of factors that become increasingly important towards the southern edge of species' ranges. The model does not predict abundance or population size. Rather it provides a prediction of relative habitat quality, which can be used to compare locations within a watershed (Figure 7 shows an example), or to make approximate comparisons of the extent of habitat potential of different watersheds.

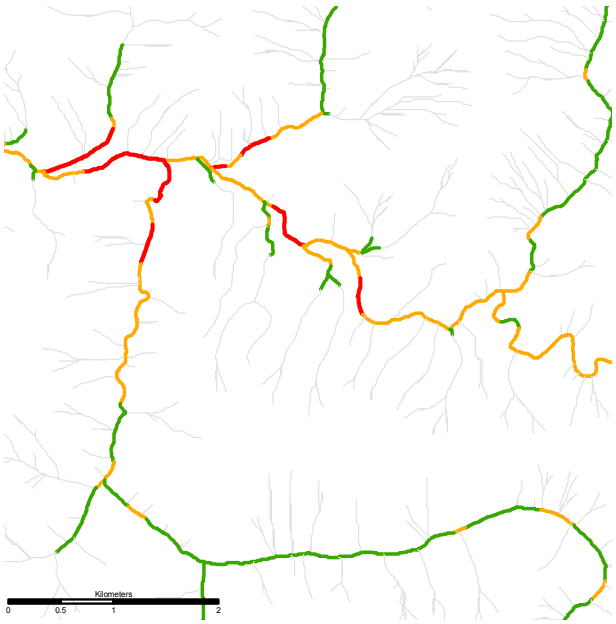


Figure 7 Intrinsic potential of coho habitat in a portion of the Bear River watershed. Red indicates stream reaches with high intrinsic potential to exhibit habitat suitable for coho salmon; yellow, areas with moderate potential; green, areas with low potential; and grey areas that are inaccessible or otherwise have negligible potential.

Currently we are intersecting the intrinsic potential results with several datasets (natural and anthropogenic) to gain an enhanced view of each watershed. For example, by masking out areas that are too hot during August (item number 4 above), and areas that are below long-standing natural barriers we sharpen our understanding of the true amount of habitat historically available for coho salmon and steelhead. Similarly, we are intersecting the intrinsic potential results with dams and with land-use and land-cover data to quantify 1) what habitat has been lost behind permanent dams, and 2) what habitat is influenced by agricultural, urban, or other detrimental land-use practices.

Historical and Recent Distribution of Coho Salmon in the Central California Coast ESU

Because of the paucity of data on population numbers of coho salmon in California rivers and streams, recent status assessments have by necessity relied on analysis of recent non-systematically collected observations of presence or absence in streams known or suspected to at one time have supported coho salmon. However, interpretation of temporal patterns in occupancy rates over the last 15 years is confounded by an expanding baseline of streams considered to have historically or recently supported coho salmon, coupled with changes in the proportion and size of streams surveyed.

Through an exhaustive search of published literature, agency surveys and reports, landowner surveys, and unpublished databases, the Team has developed a comprehensive list of streams in the Central California Coast (CCC) ESU for which historical coho salmon presence is either known or suspected. Historical observations have been ranked according to the reliability of accounts, ranging from first-hand field observations to anecdotal reports from residents or other equivocal observations. Additionally, we have compiled survey records for all known or suspected coho salmon streams for the past 15 years (5 generations), creating an extensive database of presence-absence observations for streams in the CCC ESU. These data, coupled with GIS-based estimates of watershed area, mean annual discharge, and intrinsic potential (see Research Activities – Spatial Ecology: Intrinsic Potential of Watersheds to Provide Salmonid Habitat), are being used to provide a more spatially explicit examination of coho salmon occupancy of streams within the ESU.

Preliminary analyses indicate that estimated occupancy of historical coho salmon streams has varied from about 33% to 73% over the last 15 years. Contributing to this high variability is the fact that the many identified historical coho salmon streams are in smaller watersheds with minimal habitat potential. These streams appear to exhibit more variable occupancy dynamics than the larger streams that have been the basis for most past assessments of occupancy rates. Use of smaller streams by coho salmon may be limited by lower-than-average winter flows, which may hinder access of spawners to the uppermost tributaries in some watersheds, or by low summer flows, which result in some streams dewatering or otherwise becoming unsuitable. Future monitoring of occupancy needs to include more systematic sampling that accounts for this spatio-temporal heterogeneity in environmental conditions and its consequences for the distribution of coho salmon if it is to provide meaningful information regarding ESU and population status.

Distribution of Steelhead in Central and Southern California

Basic information on the contemporary distribution and abundance of steelhead (anadromous *O. mykiss*) in central and southern California has been extremely scarce. As a first step in filling this critical data gap, we conducted a regional-scale survey of presence vs. absence for each coastal basin in which the anadromous form of the species historically occurred. Two especially large coastal basins were further subdivided into sub-watersheds. Occurrence was documented by conducting snorkel surveys of the best-occurring juvenile habitat in each basin. The data showed that occurrence of the species shows a geographic gradient, from nearly complete occupancy of watersheds in Monterey County to nearly complete extirpation south of Los Angeles (Figure 8). About two-thirds of the extirpations were associated with "barrier exclusions"—a dam or other anthropogenic barrier blocked access to all potential spawning and rearing habitat and thus excluded the steelhead from using the basin. For two-thirds of these barrier exclusions, there are recent reports of resident (non-anadromous) conspecifics in the habitat above the barrier (Figure 8). This suggests that steelhead distribution is currently more limited by loss of migration access than by outright destruction of spawning or rearing habitat.

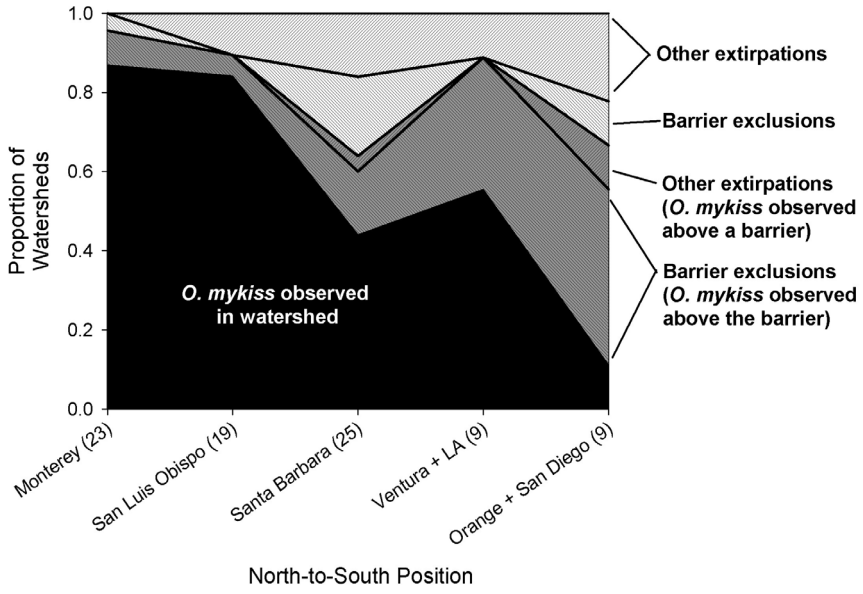


Figure 8 Current occurrence of steelhead and causes of exclusion or extirpation in southern California basins where they were present historically.

Green Sturgeon Migration and Estuary Use

While the bulk of our work is salmonid-focused, we are interested in anadromous fish in general, and have recently begun working on green sturgeon, a candidate for listing under the ESA. Green sturgeon aggregate in estuaries along the West Coast (Figure 9) during the summer where they are vulnerable to bycatch in salmon gillnet and coastal trawl fisheries. Catches in these fisheries are the best indicators of green sturgeon abundance, but interpretation of these records is problematic because the origin of the aggregations is unknown, as is the fraction of the total population in these aggregations. In collaboration with researchers at the NWFSC, Wildlife Conservation Society, USFWS, USGS, WDFW, ODWF, CDFG, Oregon State University, and UC Davis, we have initiated an acoustic and archival tagging program. We tagged 9 green sturgeon with pop-off archival tags in the Columbia River in 2004. More than 160 sturgeon have been tagged with acoustic transmitters in the Sacramento, Klamath, Rogue and Columbia rivers and Willapa Bay. Acoustic receivers have been deployed in these systems as well as several other rivers in Oregon by project collaborators and in the coastal ocean by the Pacific Ocean Shelf Tracking program (we are currently formalizing collaboration with this program) (Figure 9). Initial results are exciting: we have documented movements among many areas, indicating long-distance migrations and substantial mixing of stocks. This project was initially funded by a competitive grant from the NOAA Fisheries Office of Protected Resources though a program that was canceled in 2004. We are seeking new funding for this project, which is providing critically needed information for the management of green sturgeon.

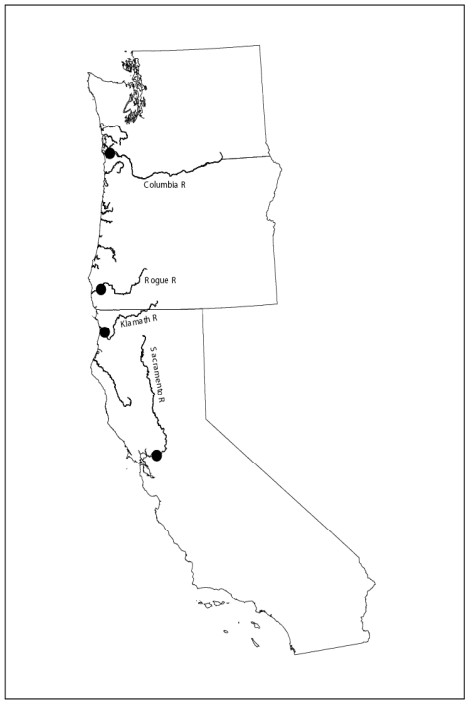


Figure 9 Major rivers used by green sturgeon. Dots indicate locations of hydrophone arrays.

Relationships of Southern California* O. mykiss *Above and Below Migration Barriers

Historical records suggest that both the anadromous and freshwater-resident forms of *O. mykiss* once occurred in nearly every coastal basin in southern California. However, the relative distribution of the two forms has been profoundly changed by two human activities: the large-scale introduction of domesticated (hatchery-raised) *O. mykiss* over the course of the past century, and the construction of large dams, bridges, and flood-control structures that block the movement of the fish within stream networks.

Currently it is unclear whether the fish populations isolated above the barriers have the potential to exhibit anadromy should connectivity be restored to the ocean. On the one hand, the life-history "decision" of anadromy vs. residency is thought to be facultative to some degree in *O. mykiss*. On the other hand, the above-dam populations may have lost the genetic potential for migration, due to natural selection, genetic drift, or genetic introgression.

We are currently collaborating with the Molecular Ecology Team and with Derek Girman's lab at Sonoma State University to address this question through the use of molecular genetics. Data on DNA sequences will be used to elucidate the relationships among existing below-barrier populations, above-barrier populations, and the hatchery stocks that were used historically to stock the area. The study has two components: an analysis of neutral markers to assess relationship-by-descent among populations, and an analysis of markers linked to selected loci to assess relationship-by-convergence. At this point tissues have been sampled (Figure 10) and are currently being analyzed. The results of the project will likely have implications for the recovery of anadromous *O. mykiss*, which is currently listed under the Federal ESA as endangered in southern California and threatened in south-central California.

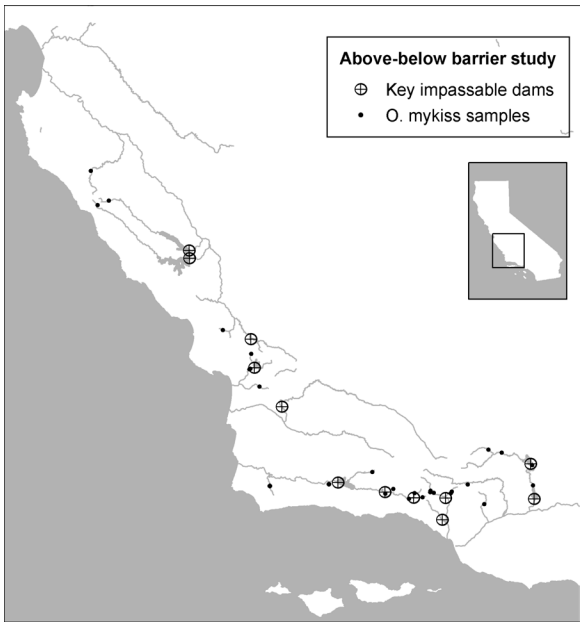


Figure 10 Sites at which *O. mykiss* tissues have been sampled, including paired sites above and below dams that currently block anadromy, and paired control sites that lack barriers.

Density-dependent Habitat Use by Juvenile Coho Salmon

We are interested in how habitat use in streams is affected by changes in population density. Importantly, density dependence has implications for population monitoring and empirical habitat modeling, because studies on salmonid distribution often neglect the potentially large influence of population size on patterns of habitat use, i.e., the distribution of individuals among pool, run, and riffle habitats within a stream. To evaluate density dependence in habitat use, we have developed statistical-modeling methods that link changes in population size to habitat-specific variability in occupancy rates, average densities, and "patchiness" in overall distribution. The methods, which have their conceptual roots in the Ideal Free Distribution, provide a means to measure density-dependent changes in habitat use, as well as to estimate the minimum population size above which secondary habitats become occupied and the maximum mean density for each habitat type. Using four years of data from Prairie Creek (see *Research Activities – Population Ecology: Survival of Coho Salmon in Habitats of Varying Quality*), we show predictable patterns of density dependence in the form of disproportionate changes in the use of secondary habitats and decreasing patchiness of distribution with increasing population size. Our results suggest that by neglecting population size, 1) modeling efforts that rely on abundance or occupancy data collected solely in primary habitat (pools) can be substantially less effective in resolving population trends than more broadly distributed metrics, and 2) empirical methods of inferring fish-habitat associations from single, "snapshot" observations can include significant bias.

Quantitative Methods

Our research on quantitative methods supports, and is driven by, our work in conservation biology, population biology, and regional ecology. Research in this area falls into several categories: estimation of population size from survey data, analysis of population dynamics, decision support, and theoretical modeling of ecological systems. Much of this work entails a statistical approach; we are especially interested in characterizing uncertainty in data and model structure, integrating this uncertainty into our analyses, and developing rigorous methods to reduce this uncertainty.

Estimation of Smolt Abundance in Small Populations

Estimates of the abundance and characteristics of smolts during their downstream migration provide information on production during the freshwater phase of the anadromous life history. Rigorous mark-recapture techniques are already available for making such estimates, but the estimators require time-stratified study designs that are not always practical in the small, coastal populations typical of California. To make the estimators useful for monitoring small populations, we developed an analytical method that aggregates stratified mark-recapture data as needed to obtain a useful estimate of abundance, while preserving as much of the structure of the data as possible (Bjorkstedt, in prep). The analysis method has been made publicly available and is used by a number of agency, industry, and private biologists to estimate abundance from smolt mark-recapture data (Bjorkstedt 2000). We have recently developed a new version of the software, which will support analysis of longer or more finely stratified data sets and includes a more robust aggregation algorithm; a stand-alone application is being prepared for public use.

We are also pursuing ways to reduce uncertainty in population estimates arising from elevated mortality rates occurring in downstream migrant traps. This work was inspired by recent field studies conducted by collaborators at Humboldt State University, in which coastal cutthroat trout that enter traps were observed to consume substantially more juvenile coho and chinook salmon than they do under natural conditions. In collaboration with researchers at the California Cooperative Research Fisheries Unit at Humboldt State University, we are designing and evaluating the performance of new live-box configurations that efficiently and effectively segregate large, potentially predatory fish from juvenile salmonids, as a way to reduce the inflated predation mortality. Preliminary results suggest that a full mesh live box with a mesh divider panel is effective in segregating trapped fish by size; statistical analysis is currently in progress to evaluate more rigorously the degree of predation of juvenile salmon in traps as a function of predator size, prey size and prey density, using data collected on predator stomach contents and the characteristics of trapped fish.

Estimation of Juvenile Abundance in Small Streams

A variety of sample survey designs have been recommended for estimation of the abundance (or density) of juvenile salmonids in small streams. These designs typically stratify the survey area into "natural" habitat units (e.g., runs, pools, riffles), and rely substantially on use of electrofishing removal methods to establish the abundance of fish in a subset of such units. Extensive use of electrofishing is not without drawbacks, however, so we have collaborated with colleagues at Humboldt State University to develop survey designs and estimators that rely instead on visual counts by divers to estimate the abundance of juvenile salmonids in small, clear streams. We propose a stratified two-phase sampling design in which a large sample of habitat-

specific units is selected for initial visual counts of the fish present. A subsample of the sampled units is selected for "calibration" to account for the probability of divers detecting individual fish. Where feasible (i.e., when the initial visual count suggests a tractable number of fish), a number of additional diver counts are made in these units and order-statistics are used to estimate a unit's "true" abundance. Overall abundance point and variance estimators were derived for this survey design, and their performance assessed via extensive simulations of repeated independent surveys applied to sampling universes constructed from empirical survey data for juvenile coho salmon in northern California (Hankin and Mohr, in prep). Note that, although electrofishing is still required to calibrate initial counts in habitat units with high numbers of fish, and in habitats for which visual counts are not feasible (e.g., riffles), this design greatly reduces the requirement for electrofishing, particularly in populations at low density.

Analysis of Presence/Absence Data

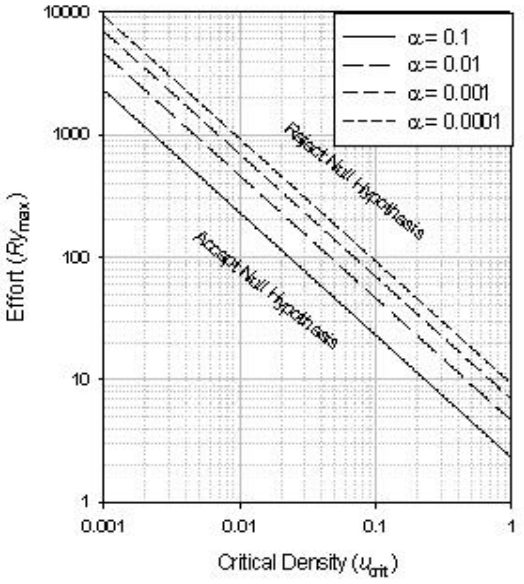


Figure 11 Survey effort required to reject the null hypothesis that a species is present in excess of a critical density.

The Team has recently developed methods for collecting and analyzing occurrence data, also known as presence/absence data. This kind of data is attractive for describing the spatial structure of animal species because it requires less sampling effort per-site to collect than abundance data and thus allows larger numbers of sites to be assessed per unit cost (an order of magnitude more sites in some cases). The problem with occurrence data is in the interpretation of observed absences, because true absence is confounded with detection-failure. There is no standard analytic method for dealing with this issue, yet it is fundamental to all distributional studies. Based on the idea that the odds of true absence vs. detection failure should depend on the level of survey effort expended (amount of habitat searched), we developed a statistical model for analyzing occurrence data. This model can be used to test the hypothesis that population density is greater than some small critical value u_{crit}, arbitrarily close to zero, using a dataset consisting solely of observed absences (Figure 11). Assuming no observation error within the sampled sites, a simple rule of thumb emerges: to test the hypothesis of 1 or more animals per y km of a linear habitat such as a creek, search $5y$ km of habitat for an α=0.01 test, and $7y$ km for an α=0.001 test. This model has been generalized to allow for observation error within sampled sites, and to habitats better described as areas or volumes.

Klamath Ocean Harvest Model

Team scientists recently directed an effort by NOAA Fisheries and the California Department of Fish and Game to overhaul a harvest management model, the Klamath Ocean Harvest Model (KOHM), a cornerstone model used by the Pacific Fishery Management Council to achieve fishery conservation objectives for Klamath River fall chinook salmon. The KOHM

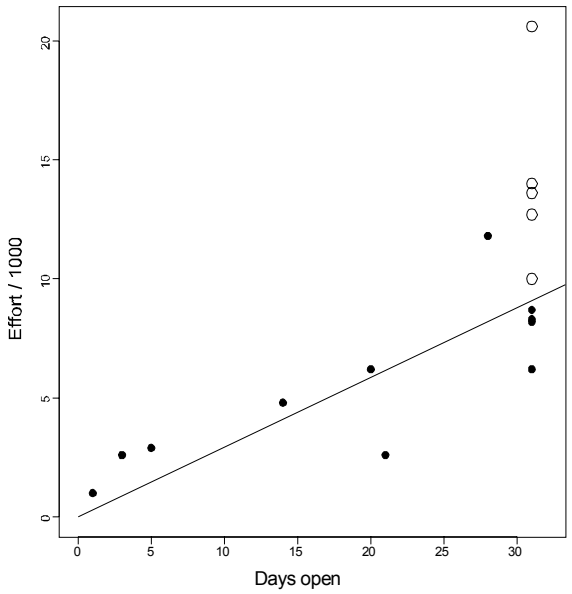


Figure 12 Recreational salmon fishing effort in Northern California during August versus days open in the month. Open circles indicate 1986–1990 data; solid circles indicate 1991–2000 data; line is ratio estimator fit to the 1991–2000 data.

predicts ocean time-area specific fishery impacts and harvest, Klamath River tribal and recreational impacts and harvest, and the numbers of fish returning to spawn naturally and at hatcheries in the Klamath River basin. The two most significant improvements we introduced to the KOHM were: 1) Development of a statistical model which allows for a rational analysis of the relationship between fishing season length and fishing effort over periods during which substantial changes in fleet size have occurred (Figure 12), and 2) development of an explicit model for the number of Klamath fall chinook encountered by the fishing gear as a function of fishing effort. The effort-prediction model has since been adopted for use as the basis for forecasting ocean harvest of ESA-listed coho salmon. More importantly, the fishery-encounter model, when coupled with the effort prediction model, allows for the use of all fisheries data collected since 1986. The previous model, developed in the late 1980s, was limited to the use of fisheries data gathered between 1986 and 1990, and relied on crude, and in some cases undocumented, methods to assess the large reductions in commercial fishing capacity that occurred during the 1990s.

State-Space Models

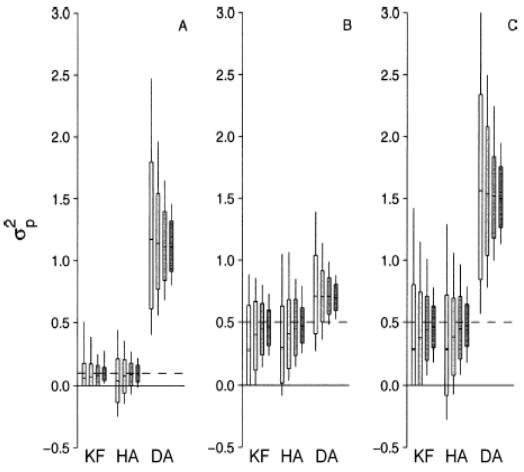


Figure 13 Performance of three process error variance estimators under different levels of process, measurement error, and time series length. KF: Kalman filter (state-space); HA: Holmes algorithm; DA: Dennis algorithm. A: small process error, large measurement error; B: large process error, small measurement error; C: both errors large.

We are utilizing state-space models in a variety of work. State-space models allow process variation and measurement error to be handled simultaneously, a great advantage when one is interested in estimating parameters of a stochastic population model from noisy data. Our early focus was on estimating the parameters of a simple extinction model using noisy data (Lindley, 2003). The state-space approach offered improved performance over available alternatives (Figure 13).

We are currently developing non-linear, non-normal state-space models for forecasting winter-run chinook juvenile abundance from time series of adult and juvenile abundance (Newman et al., *in press*). Such forecasts are needed for managing water exports and other activities in the Sacramento River.

Other ongoing projects using state-space techniques include analysis of otolith increment and microchemistry data, analysis of coded-wire tag data to detect ocean climate effects on the growth of chinook salmon, the use of multivariate models to test for migration among populations using spawner abundance time-series data, and analysis of animal movement paths to detect switching from directed migration to random foraging.

Analysis of Correlation Scales in Freshwater Disturbance Regimes

Due to the importance of covariance among populations in predicting metapopulation dynamics, we are engaged in research activities to estimate the spatial scale and intensity of disturbances in local (freshwater) habitats. Our current emphasis is on the effects of streambed scour during flood events on reproductive success of coho salmon in coastal watersheds of southern Oregon and northern California. Our approach consists of 1) assembling and standardizing data on stream discharge at a daily scale for the portion of the year during which coho salmon spawn and eggs and fry are confined to the redds (nests), 2) calculating a suite of indices of integrated disturbance for each year of record, and 3) analyzing spatial and temporal correlations in the resulting indices of annual disturbance. We calculated five disturbance indices, ranging in complexity from a simple count of the number of flood events (contiguous periods of discharge exceeding a flood threshold), to a probabilistic model that integrates the proportion of redds scoured as a function of flood intensity and the timing of floods relative to the spawning season. Analyses of spatial correlation suggest that the spatial scale of flood-related disturbance is on the order of 250-300 km (Figure 14). Current work is focused on implementing this analysis in GIS to support more rigorous analysis of the spatial pattern in flood events and predicted redd scour across and within watersheds. These results contribute to decisions regarding the spatial distribution of populations consistent with ESU viability.

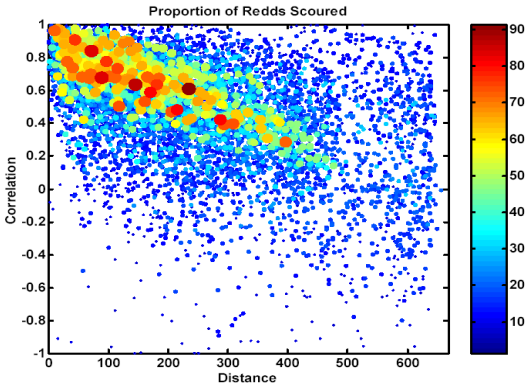


Figure 14 Spatial correlation of model predictions of redd disturbance during flood events.

Ecological Theory for Competing Metapopulations of Species with Complex Life Cycles

There is mounting evidence of competition among juvenile salmon from different populations during their time in freshwater migration corridors and in marine habitats. This suggests dispersal is not the only way in which salmon populations interact. Metapopulation theory pertinent to this situation does not appear to exist, and the consequences of using conventional metapopulation models to inform conservation and management efforts are unknown. To fill this gap we are developing a theory of spatially structured population dynamics for species with complex life cycles in which the populations occur in separate sites during some portion of their life history and share habitats during another portion. This research so far has investigated how density dependence acting at various points in the life cycle manifests in a population's dynamics, e.g., the concurrent effects of growth (fecundity) and subsequent competition for nesting sites on salmon production (Bjorkstedt 2000).

We have extended this theory to examine how competition in shared habitats and dispersal interact and affect population composition, maintenance of local adaptation, and metapopulation structure (Bjorkstedt, in prep., Figure 15). This analysis shows that competition exacerbates the consequences of asymmetric dispersal within a metapopulation, and can constrain the ability of small populations to maintain local adaptation or stave off invasion of deleterious alleles. The analysis also suggests that competition can magnify the consequences of changes in the shared habitat, such as long term shifts in ocean conditions, for small populations relative to predictions from models that lack competition. These results provide insights to 1) predicting the effects of hatchery production and changes in ocean conditions on the dynamics of natural populations and metapopulations; and 2) predicting the effects of different restoration strategies, i.e., whether to improve habitat quality (productivity) or extent (capacity) in local habitats, for local and metapopulation viability. Current work is focused on development of stochastic patch-occupancy models that include phenomenological effects of competition, and examining how the emergent density-dependence among patches influences patch-occupancy rates and persistence time of individual populations and the metapopulation as a whole.

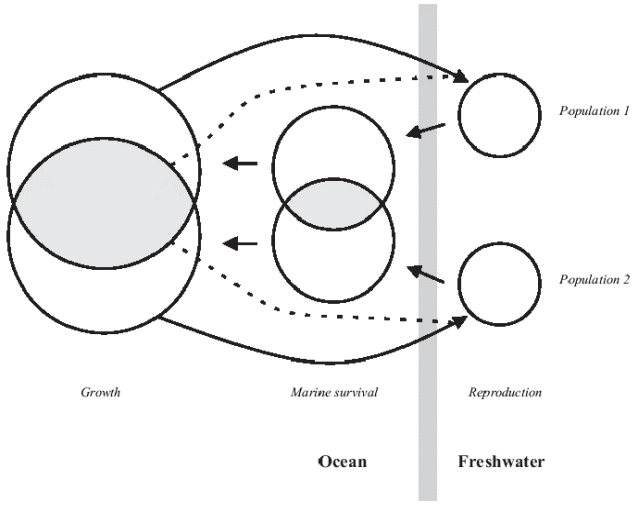


Figure 15 Schematic of competition within a salmonid metapopulation.

Estimation of Hooking Mortality

Hook-and-release mortality has become an increasingly significant source of mortality in West Coast ocean salmon fisheries, and, given the depressed status of many Pacific salmon stocks, is of great concern. In the 1990s, a new fishing technique that results in a high proportion of gut-hooked fish ("California-style drift mooching") became very popular among recreational anglers off central California. The Pacific Fishery Management Council initially assumed that the hook-and-release mortality rate assumed for the recreational troll fishery (0.08) also applied to the drift-mooch fishery. California Department of Fish and Game biologists invited Team scientists to collaborate in the design and analysis of a study to estimate directly the hook-and-release mortality rate associated with drift-mooch fishing. In the study, a total of 276 chinook salmon were caught using the drift-mooch technique and subsequently held for four days in 8,700 liter holding tanks aboard the *R/V Maiko* to evaluate mortality rates as a function of wound location. Gut-hooked fish that survived the four-day holding period but had suffered severe internal organ injuries were considered mortalities. Fish with no wounds or that suffered only superficial wounds provided a surrogate control for evaluating the effects of more severe wounds. Control-adjusted, four-day mortality rates depended strongly on hook wound location and severity (Figure 16). The distribution of wound locations in the fishery itself was estimated based on a sample of 522 fish; the relative frequency of gut-hooked fish (0.41) was twice that of any other location. The fishery overall hook-and-release mortality rate was estimated to be 0.42 (95% confidence interval of 0.34–0.50), obtained by weighting the wound-location-specific,

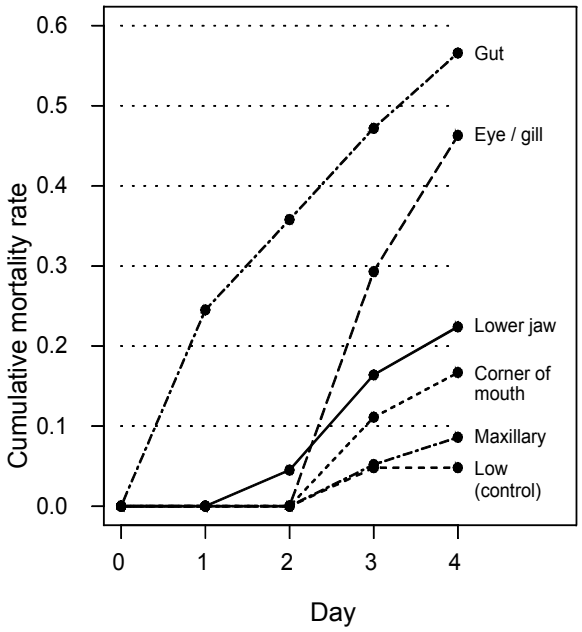


Figure 16 Cumulative mortality rate over a four day holding period by location of hook wound. Low category denotes a surrogate control group consisting of fish having no wounds or superficial wounds.

four-day mortality rates by the relative frequency of those wound locations in the fishery, and use of a sampling variance estimator derived expressly for this study design (Grover et al., 2002).

Genetic Evaluation of Visual Identification of Steelhead, Cutthroat Trout, and Their Hybrids

In contrast to surveys conducted for juvenile coho salmon, surveys designed to estimate juvenile abundance of sympatric steelhead (*Oncorhnchus mykiss*) and coastal cutthroat trout (*O. clarki clarki*) are limited by the difficulties of distinguishing the two species (and their hybrids) during diver visual surveys and electrofishing surveys. In collaboration with researchers at Humboldt State University, we have explored strategies to use genetic markers for evaluating the effectiveness of visual identification characters typically used in the field. Analysis of visual and genetic identifications (the latter based on seven single copy nuclear DNA markers) confirmed that visual identification was imperfect, and that performance deteriorated for small fish. For the visual cues used to judge the identity of fish-in-hand, trends in visual classification were biased towards identifying cutthroat in that a substantial fraction of steelhead were identified as hybrids or cutthroat trout, and a very large fraction of hybrids were classified as pure cutthroat trout. Nevertheless, once quantified, we have shown that this variance can be included in the statistical design of two-stage sampling protocols to more rigorously estimate the abundance of steelhead in systems where they are sympatric with cutthroat trout.

Based on the success of preliminary work, we are now considering ways to optimize sampling designs to estimate the total abundance of juvenile steelhead in small streams. Ongoing work includes: 1) development and testing of optimal sampling designs that (a) incorporate conventional two-stage sampling to estimate total abundance coupled with auxiliary visual identification and genetic estimation of uncertainty in classification, and (b) specify optimal allocation of sampling effort at each stage, based on estimates of uncertainty from previous surveys, and 2) re-examination of genetically identified fish to develop readily observable visual cues that provide more reliable field identification.

Graph Theory

Graph theory provides a rigorous framework in which to analyze the structure of spatial data by representing such data as a series of matrices. We use graph theory to represent an ESU scale landscape as a series of nodes (populations) and edges between nodes (drawn if two nodes are connected) (Figure 17), and take advantage of a suite of well-developed analytical exercises in order to examine the spatial structure of an ESU with respect to 1) population (node-to-node) connectivity at different dispersal thresholds, and 2) the relative importance of a population (node sensitivity) with respect to recruitment, connectivity, and risk-spreading. To look at the relative importance of each population to the ESU, we first connect the whole graph, i.e. assume a fish from one population could get to all other populations in the ESU, and use graph operations to calculate the relevant metrics for the complete ESU. By iteratively removing each population, recomputing the metrics, and examining the change in each metric, we can evaluate the relative importance of the population (Figure 18). These techniques provide a unique view of the ESU, as they illuminate which populations are important and why. This approach also

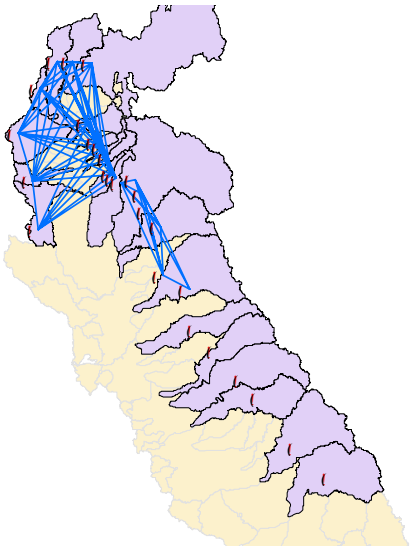


Figure 17 Nodes (populations) and edges (connections) in the CV Spring Run Chinook ESU graph at a 300km dispersal threshold.

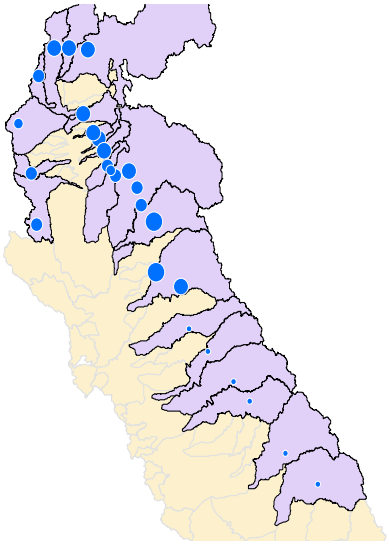


Figure 18 Relative importance of populations in terms of area-weighted connectivity for the Central Valley Spring Run Chinook Salmon ESU. Larger circles represent large well-connected populations in the historic ESU.

supports evaluation of ESU vulnerability to catastrophic risks (e.g., how is the graph connected for disturbances that are Euclidean in nature, as opposed to those carried along the stream network), and the consequences of hatchery production (e.g., how straying hatchery fish are likely to move within the ESU).

Estimation of Adult Abundance

Conservation and recovery strategies are often defined in terms of adult abundance. However, in California where many salmon and steelhead are protected for conservation, abundance for most spawning populations is poorly resolved. In large part, this is because abundance must be estimated statistically, which may incur potentially large errors from uncertainty of sampling or errors in the estimation procedure. To improve estimation, we are

developing or refining a variety of statistical-modeling techniques. First, we have developed a count-based abundance model that allows for unpredictable variability in data on salmon immigration and death. By admitting variability in longevity and detectability of adults, we permit estimation of abundance precision and, in cases where longevity changes through time, have shown large gains in estimator accuracy. Second, we are working with colleagues from the California Department of Fish and Game to improve estimation from mark-recapture of Chinook salmon carcasses. Mark-recapture is widely used in California to estimate salmon abundance, but the methods are potentially biased as a consequence of not properly modeling the underlying biological and physical processes as they pertain to carcasses. In particular, we are investigating bias due to violations of assumptions of independence and homogeneity in rates of capture and in-river retention. Finally, in cooperation with Humboldt State University, we are developing empirical regression models that could be used during surveys to classify redds that can not be directly assigned to a species. Counts of redds provide a useful metric of abundance for both salmon and steelhead, but because these species tend to overlap in distribution and time spawning, errors can arise as a result of misclassification. The results of this project are being reported as part of a Masters thesis in Fisheries Biology.

Management Support Activities

In addition to our basic and applied research to support restoration and recovery of anadromous salmonids, we have been and continue to be heavily involved in service activities that support management under the ESA and SFA.

Status Reviews

Team scientists are frequently called upon to serve on Biological Review Teams (BRTs), the mechanism by which NOAA Fisheries assesses extinction risk under the Endangered Species Act. Biological Review Teams are convened by the Science Centers upon request from the Regional Offices of NOAA Fisheries. These teams are composed primarily of scientists from the Science Centers, but occasionally include scientists from other agencies, such as the USFWS. Status reviews are written by selected members of the BRTs, and on the basis of these reviews the BRTs make recommendations to the Regional Office as to whether a given species, subspecies, or ESU is in danger of extinction, or likely to become endangered in the foreseeable future. The preparation of status reviews requires a significant time commitment devoted to gathering and analyzing data, presenting results to the BRT, preparing a draft report, and subsequently shepherding the report through an inter-agency peer-review process and final publication.

In the past 5 years, Team scientists have participated on BRTs evaluating the extinction risk for 28 ESUs or species of anadromous fish, and prepared the Status Reviews/Updates for 13 ESUs. Ten of these were prepared in late 2002 in response to three recent developments: 1) a court case (Alsea Valley Alliance vs. Evans) that invalidated a legal distinction the agency had drawn between ESA protection of wild populations and hatchery populations; 2) a pending court case (Environmental Defense Center vs. Evans) that threatens to invalidate a similar legal distinction between ESA protection of steelhead (the anadromous form of *Oncorhynchus mykiss*) and rainbow trout (the freshwater-resident form of *O. mykiss*); and 3) significant new data that include larger adult run sizes for many populations. The resulting assessments of extinction risk for these 10 ESUs were unchanged from the conclusions of the original BRTs that convened in the 1990s to assess extinction risk, although recent increases in escapement in many ESUs were considered a favorable sign by the BRT. Team members also reviewed the steelhead ESU

inhabiting the Klamath Mountain Province of northern California, and updated reviews for coho salmon ESUs throughout coastal California. The latter effort was conducted to support the State of California, which was considering listing the ESU as endangered under the California State Endangered Species Act.

Team scientists also participated on the green sturgeon (*Acipenser medirostris*) BRT and accompanying status review (Adams et al., 2002). Green sturgeon has always been low in abundance and exhibit a complex life history that is not well known. The fish spawns in certain rivers on the West Coast, are thought to spend three to five years in freshwater, migrate to the ocean, and then return to freshwater to spawn every three to five years. In addition, they appear to migrate into most West Coast estuaries including non-spawning rivers in late summer and fall, the purpose of which is unknown. Due to the lack of information on this species and therefore the uncertainty of its status, the SWFSC is likely to be involved in the listing process for the foreseeable future.

Technical Recovery Planning

Recovery planning for listed ESUs of Pacific salmon and steelhead is a very large task, and the Team bears the primary responsibility for initiating and leading the scientific aspects of the undertaking in California. Termed "Phase I" recovery planning, this work is intended to inform and support the development and implementation of recovery actions ("Phase II"), which is the responsibility of the NOAA Fisheries Regional Office. To make recovery planning more tractable, it has been organized around Recovery Domains that span the geographic range of one or more ESUs. Four of these Recovery Domains are partly or entirely included in California (Figure 19):

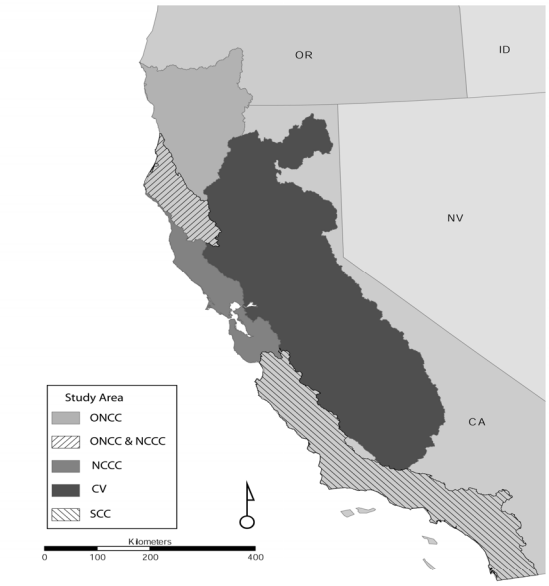


Figure 19 Recovery domains for ESA-listed anadromous salmonids in California.

- *Oregon-Northern California Coast* (ONCC), which spans the range of the Oregon Coast Coho Salmon ESU and the Southern Oregon-Northern California Coast Coho Salmon ESU and includes watersheds from the Nehalem River in Oregon (just south of the Columbia River) to the Mattole River in California;

- *North-Central California Coast* (NCCC), which spans the ranges of the Central California Coast Coho Salmon ESU, the California Coastal Chinook Salmon ESU, and the Northern California Coast- and Central California Coast Steelhead ESUs, and includes watersheds from Redwood Creek in Humboldt County to Aptos Creek in Santa Cruz County*;*

- *Central Valley (CV),* which spans the range of the Central Valley Spring-Run Chinook Salmon ESU, the Sacramento River Winter-Run Chinook Salmon ESU, and the Central

Valley Steelhead ESU, and includes watersheds throughout the Sacramento-San Joaquin drainages; and

- *Southern California Coast (SCC),* which spans the range of the South-Central California Coast and Southern California Coast Steelhead ESUs, and includes watersheds from the Pajaro River to the U.S.-Mexico border.

SPAT scientists chair and serve on technical recovery teams (TRTs) for each of these domains. A TRT consists of 8-15 scientists nominated from federal or state agencies, academia, and the private sector, and is assigned to fulfill Phase I tasks for its specific Recovery Domain. SPAT also provides the TRTs with extensive research and analytical support.

The TRTs are engaged in identifying biological viability criteria for listed ESUs of Pacific salmon and steelhead throughout California. To do so, each TRT is committed to working through a sequence of steps:

1. Identify the historical and current population structure of each ESU, with particular focus on identifying "independent populations", as defined in *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al., 2000);

2. Assess the status of each population with strong emphasis on independent populations; and for each population, identify viability criteria based on abundance, productivity, spatial structure and diversity which, if met, are expected to yield an acceptably small (5%) probability of extinction over 100 years in the face of "normal" environmental variability;

3. Identify various "viable ESU scenarios", or population configurations centered on independent populations, that are expected to yield negligible extinction risk for the ESU in the face of local or regional catastrophes and maintain the evolutionary potential of the ESU; these analyses are based on integrating contributions of population viability, location, and diversity to ESU viability; and

4. Identify data needed to reduce critical uncertainties and test central hypotheses, to assess the effects of recovery efforts, to measure progress towards recovery, and to provide guidance to research and monitoring efforts intended to collect these data in a rigorous way.

This undertaking has required SPAT to commit substantial time and energy to developing and maintaining the "infrastructure" of technical recovery planning. These efforts include:

- Intra-agency collaborations that have guided and shaped technical recovery planning, including development of the Viable Salmonid Population conceptual framework (McElhany et al., 2000), and engaging in efforts to implement consistent approaches to recovery planning in the face of regional differences in ecology and in available datasets;

- Assembling a GIS to support TRT analysis, much of which is spatial in nature (e.g., the cornerstone task of identifying the historical and current population structure of listed

ESUs). The GIS contains information on hydrography, stream flows, topography, climate, land use/land cover, geology, ecological zones, infrastructure, barriers, etc., and employs a dynamic segmentation data model to assemble information on fish distribution, the location of barriers and gages, etc., in relation to hydrographic structure; and

- Assembling and managing a staff of four analysts who conduct statistical analyses in a spatially explicit framework, and four support staff who obtain, assemble and organize available data from a broad range of sources.

Harvest Management

We participate directly in the Pacific Fishery Management Council (PFMC) and Klamath Fishery Management Council annual processes that develop regulations for the West Coast ocean salmon fishery. As members of the Councils' Salmon Technical Teams, this includes annual review of ocean salmon fisheries data, updating of various databases, forecasting abundance, numerous public meetings, and quantitative analysis of the effects of alternative regulation scenarios (time-area closures, quotas, gear restrictions, size-limits, bag-limits, etc) on stocks under PFMC management as well as ESA-listed stocks. In addition to these activities, SPAT scientists provide scientific guidance to the NOAA Fisheries Southwest Regional Office on the development of Biological Opinions and harvest Consultation (jeopardy) Standards for ESA-listed stocks, and are participating on a scoping team considering an amendment to the PFMC salmon fishery management plan that would set conservation goals for Sacramento River winter-run chinook and Central Valley spring-run chinook.

Coastal Salmonid Monitoring Plan

We are working with the California Department of Fish and Game to develop a California coast-wide monitoring plan for assessing the status and trends of all anadromous salmonids, and for measuring progress towards recovery goals for those that are listed as threatened or endangered. The Salmon Restoration Grants Program is funding the project. Progress over the past year has included the hiring of a biostatistician and a coordinator, the establishment of a steering committee, successful completion of two broadly attended workshops, the preparation of summary reports from the two workshops, and the establishment of a website to disseminate information (www.calmonitor.org). A final report of recommendations is currently being prepared.

The less tangible, but more important, goals achieved as a result of the above activities is that key members of the salmon community have reached consensus on a number of recommendations regarding the development of the monitoring plan: First, the monitoring plan should focus on assessing adult abundance at the level of entire ESUs. Second, the methods used must have quantifiable error. Third, the most promising field method to achieve this is a two-stage mark-recapture design using temporary weirs to mark and spawner surveys to recapture. Fourth, the most promising sampling design for deploying this field method among watersheds is to use a "rotating panel" design. Fifth, this method of estimating adult abundance will be used on all salmon species, but will focus on certain key populations within each ESU (so-called "functionally independent populations" that form the backbone of viability at the level of the ESU). Sixth, the remaining populations will be monitored for presence-absence of juveniles at an

extensive spatial scale, also using a rotating panel design. In addition, as part of the process various research needs have been identified for going forward with the plan.

The plan is now at the stage of transforming the general consensus into a written document. There is considerable additional work to done both because the written document brings sharper focus to decisions made about the sampling plan and because there is an additional level of detail needed to be considered in the written plan. After the written plan is completed, the biometrician will develop the estimators that will be used in the plan. In addition, the database element will be developed. Pilot studies for adult abundance and smolt out-migrant protocols are already planned and the Laboratory will be heavily involved in them.

California Hatchery Review

The California Department of Fish and Game and NOAA Fisheries conducted a joint review of California's anadromous fish hatcheries (CDFG and NMFS 2001). SPAT members participated in this review to satisfy an ESA-mandated evaluation of effects of hatchery operations on listed species, to determine whether such operations need to be authorized under the ESA. The major conclusions of the review were: 1) Central Valley fall- and spring-run hatchery Chinook salmon should be released "on-site" and not trucked to distant downstream sites; 2) a formal process should be identified for the periodic review and assessment (e.g., every 6-9 years or 2-3 brood cycles) of hatchery production levels; 3) a constant fractional marking program should be established at all hatcheries; and 4) Hatchery and Genetics Management Plans should be developed for each hatchery.

Accomplishments

Awards

- DOC Bronze Medal. 2003. For expeditiously reassessing the status of all twenty-six West Coast salmon and steelhead populations listed under the Endangered Species Act. (Adams, Bjorkstedt, Boughton, Lindley, Spence)
- DOC Bronze Medal. 2002. For theoretical and methodological contributions, which significantly advance the scientific basis for management of Pacific Coast salmon resources. (Mohr)
- PCFFA Certificate of Achievement. 2002. For outstanding work to eliminate bias in fisheries management and for outstanding achievement and perspicacity in the development of the new and improved KOHM. (Mohr)

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- Armsworth, P. R. A, C. V. Kappel, F. Micheli, and E. P. Bjorkstedt. *In review*. Working Seascapes: The Protection of Endangered Species and the Conservation of Biodiversity in Marine Ecosystems. *In:* D.D. Goble, F. Davis, and G. Heal (eds.) *The Endangered Species Act at 30: Lessons and Prospects*.
- Goslin, M. *In review*. Creating a comprehensive dam database for assessing anadromous fish passage in California. NOAA Technical Memorandum.

- Helmbrecht, S. and D.A. Boughton. *In review*. Metadata on efforts to monitor salmonid populations in the California coastal region. NOAA Technical Memorandum.
- Kraus, S. D., R. S. Schick, C. K. Slay, and S. T. Lindley. *In review*. Feasibility of linking North Atlantic right whale movements with oceanography. Marine Ecology Progress Series.
- Lawson, P. W., E. Bjorkstedt, C. Huntington, T. Nickelson, G. L. Reeves, H. A. Stout, T. C. Wainwright. *In review*. Identification of historical populations of coho salmon (*Oncorhynchus kisutch*) in the Oregon Coast Evolutionarily Significant Unit. NOAA Technical Memorandum.
- Bjorkstedt, E. P. *In press*. California Coastal Chinook salmon. Pages A113-A123 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
- Boughton, D.A. *In press*. Southern California steelhead. Pages B114-B122 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
- Boughton, D.A. *In press*. South-Central California coast steelhead. Pages B106-B113 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
- Boughton, D.A. and E. Bjorkstedt. *In press*. Central California Coast steelhead. Pages B97-B105 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
- Boughton, D.A. and E. Bjorkstedt. *In press*. Northern California steelhead ESU. Pages B84-B96 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
- Lindley, S. T. *In press*. California Central Valley steelhead. Pages B123-B133 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
- Lindley, S. T. *In press*. Central Valley spring-run Chinook salmon. Pages A131-A142 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
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- Newman, K. B., S. T. Buckland, S. T. Lindley, L. Thomas and C. Fernandez. *In press*. Hidden process models for animal population dynamics. Ecological Applications.
- Spence, B. C., T. C. Wainwright, and E. P. Bjorkstedt. *In press*. Southern Oregon/Northern California Coasts coho salmon. Pages C30-C53 *in* Updated status of listed ESUs of West Coast salmon and steelhead.West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.
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- Schick, R.S. 2002. Using GIS to track right whales and bluefin tuna in the Atlantic Ocean. *In* Undersea with GIS, D.J. Wright (ed.), ESRI Press Redlands, California.

Presentations

- 3rd International Symposium on Fish Otolith Research and Application. Townsville, Australia. 2004. (Adams, Donohoe, Royer; 2 presentations)
- 24th Annual ESRI International User Conference. San Diego, CA. 2004. (Agrawal, Schick; 2 presentations)
- 40th Annual Meeting Oregon Chapter American Fisheries Society. Sunriver, OR. 2004. (Agrawal, Bjorkstedt, Williams, Goslin, Schick, Spence, Szerlong, Williams; 2 presentations)
- 89th Annual Meeting of Ecological Society of America. Portland, OR. 2004. (Bjorkstedt, Lindley, Schick; 3 presentations)
- 100th Annual Meeting Association of American Geographers. Philadelphia, PA. 2004. (Agrawal, Bjorkstedt, Goslin, Schick, Spence, Szerlong, Williams)
- 134th Annual Meeting of American Fisheries Society. Madison, WI. 2004. (Bjorkstedt)
- Annual Meeting California-Nevada Chapter American Fisheries Society. Redding, CA. 2004. (Agrawal [invited], Bjorkstedt, Boughton, Goslin, Lindley [invited], Mohr, Schick [invited], Spence, Szerlong, Williams; 5 presentations)
- Annual Meeting Western Division American Fisheries Society. Salt Lake City, UT. 2004. (Rundio, Szerlong, Williams [invited]; 2 presentations)
- California Coastal Salmonid Monitoring Plan Workshop I. Santa Cruz, CA. 2004. (Adams, Bjorkstedt, Boughton; 7 presentations)
- California Coastal Salmonid Monitoring Plan Workshop II. Folsom, CA. 2004. (Adams, Boughton; 2 presentations)
- Coastwide Salmonid Genetics Meeting. Newport, OR. 2004. (Donohoe)
- Lower Klamath River Basin Science Conference. Arcata, CA. 2004. (Mohr [invited], Williams [invited]; 2 presentations)
- Recovery Science Review Panel Meeting. Seattle, WA. 2004. (Bjorkstedt)
- Workshop California Water and Environmental Modeling Forum. Sacramento, CA. 2004. (Adams [invited], Lindley [invited]; 2 presentations)
- 5th Salmon Ocean Ecology Meeting, Newport, OR. 2003. (Bjorkstedt)

- 21st Annual Salmonid Restoration and Urban Streams Conference. San Luis Obispo, CA. 2003. (Boughton [invited], Donohoe; 3 presentations)
- 22nd Annual Salmonid Restoration Conference. Davis, CA. 2003. (Adams)
- 23rd Annual ESRI International User Conference. San Diego, CA. 2003. (Agrawal, Bjorkstedt, Goslin, Schick, Spence, Szerlong; 2 presentations)
- PICESs Annual Science Conference, Soeul, Korea, 2003 (Grimes and Lindley invited)
- 27th Annual Larval Fish Conference, American Fisheries Society. Santa Cruz, CA. 2003. (Bjorkstedt)
- 133rd Annual Meeting of American Fisheries Society. Quebec City, Canada. 2003. (Donohoe)
- Annual Meeting California Water and Environmental Modeling Forum. Pacific Grove, CA. 2003. (Bjorkstedt, Lindley, Schick; 3 presentations)
- Annual Meeting Western Division American Fisheries Society. San Diego, CA. 2003. (Adams, Donohoe; 2 presentations)
- CALFED Environmental Water Account Salmon Workshop. Sacramento, CA. 2003. (Adams, Donohoe, Royer; 2 presentations)
- Ecology and Evolutionary Biology seminar series, University of California. Santa Cruz, CA. 2003. (Boughton [invited])
- Lower American River Science Conference, Sacramento, CA. 2003. (Donohoe)
- Recovery Science Review Panel Meeting. Santa Cruz, CA. 2003. (Adams, Bjorkstedt, Boughton, Donohoe, Lindley, Williams; 6 presentations)
- State of the Estuary Conference: New Science, Gaps, and Management Considerations. Oakland, CA. 2003. (Adams)
- 132th Annual Meeting of American Fisheries Society. Baltimore, MD. 2002. (Schick [invited])
- Annual Meeting California-Nevada Chapter American Fisheries Society. Lake Tahoe, CA. 2002. (Bjorkstedt)
- Annual Meeting California Water and Environmental Modeling Forum. Asilomar, CA. 2002. (Lindley)
- Annual Ocean Sciences Meeting American Geophysical Union. Honolulu, HI. 2002. (Schick)
- CALFED Environmental Water Account Salmon Workshop. Sacramento, CA. 2002. (Lindley)

Committees and Service

- CALFED Central Valley Salmon Escapement Project Work Team (Pipal)
- CALFED Central Valley Salmon Project Work Team (Adams)
- KFMC Klamath Ocean Harvest Model Workgroup (Mohr [chair])
- KFMC Klamath River Technical Advisory Team (Mohr)
- NMFS California Central Valley Technical Recovery Team (Lindley [chair])
- NMFS Green Sturgeon Biological Review Team (Adams [chair], Lindley)
- NMFS North-Central California Coast Technical Recovery Team (Bjorkstedt [chair], Spence)
- NMFS Oregon and Northern California Technical Recovery Team (Williams [co-chair])

- NMFS South-Central California Coast Technical Recovery Team (Boughton [chair], Adams)
- NMFS Southern Oregon/Northern California Coast Workgroup (Williams [chair])
- NMFS West Coast Salmonids Biological Review Teams (Adams, Bjorkstedt, Boughton, Lindley, Spence, Williams)
- NMFS/CDFG California Coastal Salmonid Monitoring Plan, Steering Committee (Adams [co-chair], Boughton)
- NMFS/CDFG California Coastal Salmonid Monitoring Plan, Plan-writing Subcommittee (Boughton)
- NMFS/CDFG California Coastal Salmonid Monitoring Plan, Southern California Subcommittee (Boughton)
- NMFS/CDFG California Coastal Salmonid Monitoring Plan, VSP Subcommittee (Bjorkstedt)
- NMFS/CDFG Salmon and Steelhead Hatchery Assessment Workgroup (Adams, Lindley)
- NMFS/CDFG Salmon and Steelhead Hatchery Assessment Workgroup, Trucking Subcommittee (Lindley)
- PFMC California Central Valley Chinook FMP Amendment Interagency Workgroup (Mohr)
- PFMC Salmon Technical Team (Mohr)
- SWFSC Liaison to Recovery Science Review Panel (Bjorkstedt)
- USGS Humpback Chub Population Estimation Independent Review Panel (Lindley)

Additional Service

- *Adjunct professor*. Duke University, Nicholas School of the Environment and Earth Science (Lindley)
- *Adjunct professor*. Humboldt State University, Department of Fisheries Biology (Bjorkstedt)
- *Course instructor*. Applied workshop on salmon escapement tag-recovery models and estimation. 2004. (Szerlong)
- *Journal referee.* American Naturalist, California Fish and Game, Canadian Journal of Fisheries and Aquatic Sciences, Climatic Change, Conservation Biology, Ecology, Environmental Management, Fishery Bulletin, Herpetologica, Herpetological Review, Journal of Fish Biology, Journal of Herpetology, Marine Ecology Progress Series, North American Journal of Fisheries Management. 2002–2004. (Bjorkstedt, Boughton, Lindley, Rundio, Spence)
- *Mentor*. California State University, Monterey Bay, Intern Program. 2004. (Boughton)
- *Mentor*. University of California, Santa Cruz, Environmental Studies Intern Program. 2002. (Williams)
- *Scientific advice*. Coho salmon south of San Francisco delisting petition to CDFG. 2004. (Adams)
- *Scientific advice*. NOAA Fisheries' artificial propagation policy. 2004. (Adams, Lindley)
- *Scientific review*. *O. mykiss* resident-anadromous portion of NOAA Fisheries status review update. 2003. (Adams)
- *Statistical review*. CDFG proposed sampling programs and estimation methods for California ocean recreational fishery. 2003. (Mohr)

- *Statistical review*. CDFG spot prawn trawl bycatch study at request of SWR. 2004. (Mohr)
- *Statistical review*. Sample size requirements for determining age-composition in Central Valley salmon spawner escapement surveys. 2002. (Mohr)

Extramural Research Support

- *Green sturgeon marine migration and estuary use*. 2003. NOAA Fisheries Office of Protected Resources, Candidate Species Program: $55,000.

Future Research Directions

We are developing a strategic research plan that exploits the Team's broad capabilities and focus, and that continues to pursue a useful combination of empirical work, theoretical study, and rigorous statistical analysis. The Team has several developing lines of research, all of which directly contribute to the Team's mission and focus on population dynamics. A few of these research programs exist as continuations of recently initiated studies described previously. For example, contingent on finding suitable funding, work on green sturgeon will be extended to identify in-river holding and spawning habitats and to develop abundance estimates that account for the life history and spawning periodicity of these fish. Here, we highlight major themes and representative examples of new research. These research programs bring to bear state-of-the-art field studies, laboratory methods, analytical approaches, and theoretical synthesis.

Population Dynamics – Abundance Time Series

A primary effort of the Team is to foster and develop the collection of long-term data sets on the abundance, distribution and structure of salmonid populations in California. These activities include the direct collection of life-cycle data and the encouragement and technical support of data collection efforts by other groups and agencies. In addition, we focus our efforts on developing and evaluating new methods and technologies for collecting data that has historically been considered infeasible to collect.

As an example, we anticipate a proof-of-concept project that applies a novel technology, the DIDSON acoustic camera, to monitor salmon or steelhead runs in California streams where monitoring is currently considered infeasible due to 1) the extremely small sizes of the runs, which require that a highly accurate monitoring method be used, and 2) the prevalence of dramatic high-flow events that prevent the effective use of weirs or visual surveys.

Dynamics of small populations and metapopulations

Many populations of coastal steelhead and coho salmon may never have been large, yet it seems that they have persisted for long periods of time. We seek to understand the mechanisms by which such small populations persist in the face of extreme environmental variation. We are approaching this question through studies of population structure, migration, and habitat use, and by developing theory grounded in empirical observations.

We have recently initiated three studies to investigate the dynamics of small populations and metapopulations of anadromous salmonids, and in particular, the ecology of small populations of steelhead throughout coastal California. First, we have initiated research to

examine the factors that allow populations of steelhead in small basins along the Big Sur coast to persist at apparently high densities despite their relatively small size and frequent watershed disturbance. This work focuses on the potential roles of (1) food web interactions, especially subsidies of terrestrial prey to steelhead in systems with little input of marine-derived nutrients, and (2) movement within and between basins.

Second, we have initiated research to examine how the climate of southern California interacts with the hydrologic system to structure the steelhead metapopulation, and the evolutionary ecology of steelhead within this milieu. In particular, we are interested how the suitability and distribution of freshwater habitats change over time, and the adaptations of the species to this dynamic template. Using the subpopulations inhabiting the Santa Clara basin as a study system, we have recently begun preliminary work on the interaction of feeding opportunities and water temperature on measures of habitat quality, such as steelhead growth, survival, and short-distance movements, during the stressful summer months. We are seeking funding to extend significantly the spatial extent of this study through the use of helicopter-borne infrared imaging as a tool to characterize the thermal environment of steelhead in watersheds throughout southern California.

Third, in collaboration with colleagues at Humboldt State University, we are taking advantage of a natural experiment arising from recent wildfires along the Lost Coast to examine the consequences of fire disturbance on small populations of steelhead. The wildfires occurred almost immediately following completion of a comprehensive survey of steelhead populations along the Lost Coast, and thus allow us to pursue a rigorous before-after, control-impact study of the response of steelhead populations along a gradient of fire-related disturbance.

Life History Diversity

Salmonids, especially steelhead and Chinook salmon, have complex life histories and exhibit great diversity in the expression of life history traits among populations and among individuals within populations. We hypothesize that such variability is important to the persistence of salmonid populations, particularly at the edge of their range. We seek to characterize this variability, understand how it relates to the unique environmental characteristics found in California, and explore the consequences of these relationships for the viability of populations.

Characterizing life history variability and examining its consequences for population persistence is an important focus of recently initiated studies on the population ecology of steelhead in central and southern California (see above). A critical element of this work will be the use of otolith microchemistry to distinguish relationships between anadromous and resident forms of steelhead. We are also examining the causes and consequences of recently documented variability in the freshwater life history of coho salmon through the use of theoretical models motivated by study of the bioenergetics of juvenile coho salmon in streams of northern California and recent work on intra- and interspecific competition among juvenile salmonids in small streams.

Economics Team

Introduction

The Economics Team includes two permanent FTEs and is recruiting a third. The Team also currently includes two postdocs and two GIS analysts. The Team provides data, methods and analyses needed to address economic issues associated with (1) protection of salmonid stocks listed under the Endangered Species Act (ESA), and (2) NOAA Fisheries' groundfish and salmon fishery management responsibilities under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Team members disseminate research results in journals and at conferences. They also participate on advisory committees that make technical recommendations to fishery managers.

The Team's approach to data collection and research is highly collaborative. For instance, the Team's habitat economics research is intended to complement work being done by the SPAT in the area of salmon recovery planning. Virtually all of this research involves cooperative arrangements (i.e., sharing of costs, data, models and/or expertise) with agencies such as the California Department of Fish and Game (CDFG), Pacific States Marine Fisheries Commission (PSMFC), Jackson State Demonstration Forest and U.S. Forest Service (USFS). The Team's fishery data collections are planned and conducted in coordination with other economists - e.g., at other NOAA Fisheries laboratories, PSMFC and the Pacific Fishery Management Council (PFMC) - who have a mutual interest in groundfish and salmon. Research is typically done in collaboration with academics and postdocs.

To augment its base budget, the Team routinely responds to requests for proposals issued by the Economics and Social Research Branch (ST5), NOAA Fisheries, Silver Spring. The Team has also obtained support from other NOAA Fisheries sources (marine mammal and Fisheries Information System funding) and from the U.S. Department of Agriculture.

Objectives

- to address requirements for economic analysis under the ESA, including the requirement to estimate costs associated with implementing recovery plans
- to develop models that systematically address issues pertaining to how habitat restoration objectives can be met with limited resources
- to conduct economic surveys that provide information on the range of activities engaged in by groundfish and salmon fishery participants (commercial and recreational), the value of these activities, and the characteristics of the participants
- to develop analyses and models that address fishery management problems and provide insights into how fishing behavior and the economic value of fisheries are affected by economic, biological and regulatory factors
- to provide economic expertise and advice to policy makers.

Research and Management Support Activities

Data Collection and Research – Habitat

The ESA requires that recovery plans for listed species include "estimates of ... the cost to carry out those measures needed to achieve the plan's goals and to achieve intermediate steps toward that goal" (ESA, Section 4(f)(1)(B)(iii), p.13). Habitat restoration is expected to be a major component of the recovery plans being developed for ESA-listed salmonids in California. The Team has initiated several projects that are intended to facilitate estimation of habitat restoration costs.

California Habitat Restoration Project Database (CHRPD

Data on habitat restoration projects in California are fragmented among different funding entities, not maintained in a standardized format and not readily accessible. The objectives of this project are to: (1) inform recovery teams regarding the nature and extent of historical restoration efforts by providing a comprehensive inventory of salmonid habitat restoration projects in California, and (2) obtain cost and other project-specific information that can be used, with other relevant data, to estimate models that predict habitat restoration costs. The PSMFC, in collaboration with the Team, designed and created the CHRPD - an Access 2000 database that provides a standardized structure for describing habitat restoration projects in terms of cost and other types of project-specific features. The PSMFC has spent the past four years working with major restoration funding entities in California to incorporate their restoration projects into the CHRPD. In recent years, CDFG has supplemented the funds provided by the SCL with additional monies to continually update the CHRPD with newly funded CDFG projects and to add a grants tracking module to the database; CALFED has also provided funding to add its projects to the database. While the CHRPD has largely succeeded in achieving the first objective (providing an inventory of restoration projects), achieving the second objective has been more difficult, as the types of project-specific cost data that are readily available from funding entities are typically not sufficiently detailed to be useful for cost modeling. The Team has requested that the PSMFC redirect its efforts from collection of data on new projects to interviewing leaders of existing projects to obtain the types of detailed data needed for cost analysis. Once an adequate sample of detailed project costs is obtained, the SCL intends to phase out its support for the CHRPD. Although CDFG and CALFED provide some support for the CHRPD, it is not clear whether these funding sources will be adequate to ensure the continued existence of the database once the SCL funding ceases. (Funding: SCL)

Habitat Restoration Cost Workshop

Restoration practitioners have considerable knowledge and experience that would benefit the Team in their efforts to specify habitat restoration cost models. To tap this knowledge, the Team - in coordination with the PSMFC and SWR - organized a workshop to solicit expert advice regarding factors affecting restoration costs and the feasibility of developing standardized methods for estimating restoration costs on the scale of a watershed or ESU. The workshop was attended by engineers, foresters, geologists, hydrologists, biologists and economists representing a variety of federal, state and local agencies and non-governmental organizations. Workshop presentations and discussions focused on cost issues associated with five types of restoration activities - road maintenance/decommissioning, riparian restoration, instream treatment, fish

screens, and wetland creation/restoration. *Proceedings of the Salmon Habitat Restoration Cost Workshop* was recently published. (Funding: F/PR, SCL)

Salmonid Habitat Restoration Cost Models

The objective of this project is to use project-level data from the CHRPD (e.g., project cost, work type, location, "size"), in conjunction with other relevant data on landscape features and economic conditions at the project site, to estimate models that predict habitat restoration costs. The Team has been working with GIS analyst Kelly Hildner (UC-Santa Cruz) to obtain spatial data on landscape and economic variables that are expected to affect restoration costs, link these variables to data on individual projects contained in the CHRPD, and estimate restoration cost models with the composite data set. Significant progress has been made in collecting data on landscape features (e.g., elevation, soil erodability, land use) and economic conditions (e.g., unemployment rates, wage rates in the construction industry) and linking these variables to the individual projects in the CHRPD. Considerable effort has also been spent identifying appropriate spatial models and making preliminary model runs. As indicated above, PSMFC is initiating efforts to collect more detailed project-specific cost data than are currently available in the CHRPD; more definitive model estimation awaits receipt of that data. (Funding: S&T, SCL)

A major challenge in efforts to restore endangered salmonid populations is targeting recovery activities effectively. To address this issue, the Team is developing models to support decision-making in the protection and restoration of freshwater salmon habitat. To date, this work has focused on the control of erosion and sediment loading—thought to be a major impediment to salmon recovery in many northern California streams—and the removal of fish passage barriers so as to maximize fish habitat quantity and quality.

Logging Road Management Mode

The Team has developed a model of logging road management that identifies the treatment (road removal, road improvement, or maintenance of the status quo road) that minimizes the long-run expected cost of erosion control on a road. This cost is a function of road characteristics, the observed level of erosion, and the inter-annual variability in road erosion. The model uses stochastic dynamic programming to capture two key features of the problem: uncertainty about erosion levels and the manager's option to delay irreversible decisions. This work has been done in collaboration with Bill Baxter and Marc Jameson (California Department of Forestry), Teresa Ish (masters graduate in Marine Science and Fisheries Management, UC-Santa Cruz), and graduate student Matt Thompson (Dept of Industrial Engineering and Operations Research, UC-Berkeley). (Funding: S&T, USDA, SCL)

Collection of Road Erosion Data

A related project, starting in the fall of 2004, is the installation of erosion-measuring devices on the Jackson Demonstration State Forest. Settling basins with tipping buckets and ISCO samplers will provide data on three key variables of interest—coarse sediment, fine sediment, and total runoff—on road segments with varying characteristics. This effort is a pilot project, with future development of the project depending on the quality of data derived from the first two rain years. The project is being carried out in collaboration with Bill Baxter (California Department of Forestry) and Liz Keppeler (USFS Redwood Sciences Laboratory). The data

collected will be used to improve the logging road management model, which currently relies on simulated rather than empirical estimates of erosion. (Funding: S&T, SCL)

Spatial Watershed Management Model

The Team is developing a spatial watershed management model that assesses the compatibility of timber production with erosion reduction efforts such as the relocation of roads from inner stream gorges to upper slopes. The rationale for this effort is that large areas of coastal salmon habitat are owned by commercial timber companies or other landowners wishing to harvest timber and that quantitative model provide a framework for identifying management measures that minimize erosion given particular harvest plans (or, conversely, that maximize the profitability of timber production given limits on allowable sedimentation). The model identifies, at the watershed scale, the optimal siting and timing of road maintenance, road removal, and timber harvest activities. The technique used is large-scale mixed-integer programming with linear relaxation. The Team is conducting this project in collaboration with postdoc Jongbum Kim (Department of Environmental Engineering, Johns Hopkins University) and the California Department of Forestry. (Funding: USDA)

Fish Passage Barrier Removal

The Team has developed a model of optimal allocation of expenditures on removing fish passage barriers in salmon-bearing streams. Specifically, the model solves the problem of which passage barriers should be removed in order to maximize the gain in habitat accessibility for salmon, given some budget. The model has been applied to four watersheds in Washington State, identifying allocations that are up to 25% more efficient than standard sorting and ranking procedures. The project was carried out with graduate student Jesse O'Hanley (Dept of Environmental Science, Policy and Management, UC-Berkeley).

The Regulatory Flexibility Act (RFA) requires that effects of Federal regulations on small businesses be identified and mitigated to the extent possible. Addressing this requirement for listed salmonids is complicated by the broad range of businesses potentially affected by ESA regulations. Under the Team's guidance, Ann Mullen and Kelly Hildner (UC-Santa Cruz) assembled a database and Hildner designed a query interface to facilitate consideration of RFA requirements.

ESA Small Business Database and Query Interface

The ESA small business database relies on two U.S. Census data sources: County Business Patterns (collected annually) and Census of Agriculture (collected every five years, most recently in 2002). Data on 92 industries potentially affected by ESA regulations were selected from County Business Patterns for inclusion in the database. Data on these 92 industries plus the agricultural sector are provided for all counties in California, Oregon, Washington and Idaho. The County Business Patterns query interface allows the user to display information for each of the 92 industries on employment, payroll, and number of establishments in each of 13 size categories for selected years (1998-2001) and geographic areas. The Census of Agriculture query interface allows the user to display number of farms by farm type, number of farms by sales category, and total sales by sales category for selected years (1997, 2002) and geographic areas. The geographic area options include a choice of counties, ESUs, recovery domains and study areas. Small Business Administration (SBA) standards for what constitutes a small

business are also included in the database. Although the Census data categories do not always correspond well with the SBA standards and the Census data are less than timely (due to the time lag between collection and publication of Census business data), the Census is often deemed the best available data source for RFA analysis as it relates to ESA salmon regulations. (Funding: S&T)

Data Collection and Research - Recreational and Commercial Fisheries

Management restrictions placed on one fishery may also affect fish stocks harvested in other fisheries (e.g., due to displacement of effort from the regulated fishery). To evaluate both direct and indirect effects of groundfish and salmon regulations, economic surveys are needed that cover the entire range of activities engaged in by groundfish and salmon fishery participants. The Economics Team has been actively involved in the planning and implementation of recreational and commercial fishery surveys involving collection of such data.

Economic Survey of Pacific Coast Commercial Passenger Fishing Vessels (CPFVs)

This survey was a collaborative effort involving not only the Team but also S&T, PSMFC and the SWR. The objectives of the survey were to obtain the data needed to (1) characterize the CPFV fishery in terms of fishing patterns, revenues and costs, (2) estimate the economic value of the fishery, and (3) predict the effects of regulation on CPFVs and the value of the CPFV fishery. The PSMFC created a license frame consisting of all state-licensed CPFV operators who participate in the marine recreational fishery in their state. Telephone interviews were conducted of CPFV operators randomly selected from the license frame. The survey was completed in 2002. (Funding: S&T)

Economic Survey of Freshwater Salmon/Steelhead Anglers in California

The objectives of this survey are to obtain the data needed to (1) characterize the freshwater recreational salmon/steelhead fishery in California in terms of effort, expenditures and angler characteristics, and (2) develop models that predict the effect of changes in hatchery production on fishing effort and the economic value of fishing on major salmon/steelhead rivers in California. This telephone survey is being conducted by CIC Research, a PSMFC subcontractor. Survey respondents are drawn from a random sample of steelhead report card holders (using telephone contact information obtained from CDFG's steelhead report card database) and a random sample of freshwater salmon anglers residing in 23 central/northern California counties (using contact information for recreational license holders that CDFG began collecting in 2004). The survey will be completed in early 2005. (Funding: SCL)

Economic Logbook Program for California Nearshore Groundfish Permit Holders

Although landings data are available for the nearshore *sebastes* complex as a whole, detailed catch information for individual species are limited. Cutbacks in port sampling coverage have reduced the precision with which the species composition of nearshore rockfish landings can be estimated. Available area of catch data are not considered reliable and (even if reliable) are not reported on landings receipts on a sufficiently fine spatial scale to be useful for management. Little is known about the extent of discard, as most nearshore vessels are too small to accommodate an onboard observer. Other than ex-vessel prices, little economic information is available regarding the fishery. Given the current lack of data and stock assessments, nearshore rockfishes are managed by conservative OYs that do not take into consideration differences

among regions and gear types with regard to harvest and discard of the various species. The Economics Team is working with nearshore fishermen, CDFG and PSMFC to create a logbook program that will (1) provide the data needed to address some of these management issues, and (2) facilitate development of models that predict the effects of regulatory changes on harvest, effort and the economic value of the fishery. A draft logbook form has been developed, along with maps for coding area of catch, and the PRA approval process has been initiated. A September 10 meeting is being convened to finalize the logbook form, solicit volunteers to participate in the pretest, discuss quality control procedures, and formulate ideas regarding web access to data summaries. (Funding: S&T, FIS)

Economic Survey of Pacific Coast Commercial Groundfish/Crab/Shrimp/Salmon Vessels

The objective of this survey is to collect data needed to (1) characterize the behavior of participants in the salmon and groundfish fisheries, as well as their participation in other fisheries (e.g., crab, shrimp), and (2) evaluate the effects of regulations on these fisheries. Although this survey was initiated by the NWFSC, the NWFSC economists have worked closely with SCL economists on designing the survey instrument, ensuring that California nearshore groundfish permit holders are adequately represented in the sample, and preparing the PRA submission. PSMFC implementation of the survey is expected to occur in late 2004/early 2005. (Funding: S&T)

In addition to collecting fishery data, the Team develops models that provide insights into the effects of biological, economic and regulatory changes on fishery behavior and the economic value of the fishery:

Real Options Models

The Team has developed a suite of investment and participation models using 'real options' techniques from financial economics. The motivation for this approach is two-fold. First, there is a significant amount of latent capacity in the commercial salmon fishery, a pattern observed in many limited-entry fisheries, and a better understanding of the causes and consequences of this latent effort can contribute to fisheries management. Second, data on this fishery are largely limited to landings receipts, so there is no empirical basis for developing more elaborate behavioral models. Proceeding from a simple model of a fisherman's decision to enter/exit a single fishery, the team has developed several extensions such as a multi-factor model (allowing price and quantity to appear as separate variables) and a model with stochastic salvage value. Current work being conducted by postdoc Baishali Bakshi (Dept of Economics, UC-Irvine) is focused on model testing and on development of a model of switching behavior, in which a fisherman may choose among several fisheries. Applied mathematician Valentina Bosetti (Fondazione Eni Enrico Mattei, Milan, Italy) is working with the Team on these efforts. (Funding: S&T, SCL)

Measuring Technical Efficiency in Commercial Fisheries

The Team is developing a Bayesian hierarchical approach to measuring technical efficiency in commercial fisheries. This work provides a framework for assessing the impact of regulations on fishing enterprises and for characterizing a production function that accounts for both the highly stochastic environment of commercial fisheries and the effect of boat-specific unobservable such as skipper skill. Statistician Garth Holloway and economist Xavier Irz (Dept of Agricultural and Food Economics, University of Reading, U.K.) are collaborating with the

Team on this work. (Unfunded)

Pinniped-Fishery Interactions on the Pacific Coast

The objectives of this project are to (1) analyze existing data sources to determine the nature and extent of pinniped-fishery interactions and how these effects vary by fishery, year, season and location, and (2) provide recommendations whether and how data collections might be improved to further clarify our understanding of such interactions. The Team has identified and obtained existing data sources pertaining to pinniped-fishery interactions, has spent extensive time cleaning up some of the databases, and is working with GIS analyst Miguel Castrence (Clark University) on the analysis. This project will be completed in mid-2005. (Funding: NWR, with marine mammal $)

Behavioral/Valuation Model for Pacific Coast Marine Recreational Anglers

The Team, in collaboration with postdoc Deqin Cai (Dept of Agricultural and Resource Economics, Oregon State University), developed a random utility model (RUM) that depicts angler decisions regarding fishing mode, target species, fishing site and season. The model also predicts how effort would shift among modes, species, sites and seasons in response to specific types of fishery/area/season closures and the changes in economic value associated with such shifts. Estimation of the RUM has been completed, using data collected in a 1998 economic survey of Pacific coast marine recreational anglers. A paper that discusses model results is currently in preparation. (Funding: S&T)

Publications

- Holloway, G., D. Tomberlin, and X. Irz. In press. Hierarchical Analysis of Production Efficiency in a Coastal Trawl Fishery. In: Alberini, A. and R. Scarpa (eds.). Applications of Simulation Methods in Environmental and Resource Economics. Boston: Kluwer Academic Press.
- Ish, T., and D. Tomberlin. In press. Simulation of Surface Erosion on a Logging Road in the Jackson Demonstration State Forest. In: Proceedings of the 2004 Redwood Region Forest Science Symposium. Berkeley, CA: University of California Center for Forestry.
- O'Hanley, J., and D. Tomberlin. In press. Optimizing the Removal of Small Artificial Fish Passage Barriers. Environmental Modeling and Assessment
- Tomberlin, D. and V. Bosetti. In press. Solving Real Options Models of Fisheries Investment When Salvage Value Is Difficult to Estimate. In: Proceedings of the 2004 IIFET Convention. Corvallis, OR: International Institute for Fisheries Economics and Trade.
- Allen, S.T., C. Thomson and R. Carlson (eds.). 2004. Proceedings of the Salmon Habitat Restoration Cost Workshop. Portland, OR, Pacific States Marine Fisheries Commission.
- Bosetti, V., and D. Tomberlin. 2004. Real Options Analysis of Fishing Fleet Dynamics: A Test. FEEM Natural Resource Management Working Paper 102. Milan: Fondazione Eni Enrico Mattei.
- Scientific and Statistical Committee. 2004. Marine Reserves: Objectives, Rationales, Fishery Management Implications and Regulatory Requirements. Portland: Pacific Fishery Management Council.

- Thomson, C. 2004. Conclusions and recommendations. In: Allen, S.T., C. Thomson and R. Carlson (eds.). Proceedings of the Salmon Habitat Restoration Cost Workshop. Portland, OR, Pacific States Marine Fisheries Commission.
- Tomberlin, D. 2004. The allocation problem in habitat restoration. In: Allen, S.T., C. Thomson and R. Carlson (eds.). Proceedings of the Salmon Habitat Restoration Cost Workshop Portland, OR: Pacific States Marine Fisheries Commission.
- Buongiorno, J., S. Zhu, D. Zhang, J. Turner, and D. Tomberlin. 2003. The Global Forest
- Products Model: Structure, Estimation, and Applications. New York: Academic Press
- Tomberlin, D. 2002. Modeling California salmon fleet dynamics. In: Proceedings of the North American Association of Fisheries Economists. New Orleans.
- Tomberlin, D. and J. Buongiorno. 2002. Timber plantations, timber supply and forest conservation. In: Palo, M. (ed.). World Forests, Markets and Policies. Kluwer Academic Publishers.

Presentations

- International Institute of Fisheries Economics and Trade, Tokyo, Jul 2004 (Tomberlin)
- UC-Santa Cruz Marine Policy class, Apr 2004 (Thomson)
- 2004 Redwood Regional Forest Science Symposium, Santa Rosa CA, Mar 2004 (Ish)
- North American Association of Fisheries Economists, Williamsburg VA, May 2003 (Tomberlin)
- Salmonid Restoration Federation, San Luis Obispo CA, Mar 2003 (Tomberlin)
- Society of American Foresters, Winston-Salem NC, Oct 2002 (Tomberlin)
- American Fisheries Society Cal-Neva Chapter, Lake Tahoe, Apr 2002 (Tomberlin)

Committees and Service

- Member, PFMC Scientific and Statistical Committee (Thomson)
- Chair, SSC Marine Reserve Subcommittee (Thomson)
- SWFSC representative on the RecFIN Committee (Thomson)
- NOAA Fisheries mentor for James Hilger (Department of Agricultural and Resource Economics, UC Berkeley), recipient of Sea Grant Graduate Student Fellowship in Economics (Thomson)
- Review manuscripts, agency reports and research proposals - Marine Resource Economics; European Association of Environmental and Resource Economists Proceedings; CalCOFI Reports; NOAA Fisheries, USDA and USGS agency reports; Sea Grant, S-K and West Coast Groundfish Cooperative Research proposals (Thomson, Tomberlin)
- Recruitment committee for Sea Grant economist, Sep 2004 (Thomson)
- Participated in “Straight Talk” meeting between marine scientists and fishing community organized by Sea Grant, Apr 2004 (Thomson)
- Attended three recreational constituent meetings - Hillsborough, San Luis Obispo, Dana Point; Mar 2004 (Thomson)
- Santa Cruz Lab Library Committee (Tomberlin)
- Santa Cruz Lab Matlab Coordinator (Tomberlin)

Program Development

- Hire FTE economist (recruitment now underway)
- Continue to work on funding proposals; administer grants and contracts; recruit postdocs and other temporary staff
- Continue to collaborate with other NOAA Fisheries, PSMFC and PFMC economists on fishery data collection efforts
- Continue to collaborate with academics (and soon-to-be-hired Sea Grant economist) on research projects
- Seek support for habitat and protected species data collection and research

Future Research Directions

Habitat

- A major limitation to the usefulness of the logging road management model is that few landowners have good data on how much erosion actually occurs on their roads. To address this limitation, the Team will be developing a partially observable Markov decision model, which optimizes over beliefs about erosion levels rather than assuming that erosion levels can be directly observed. This approach allows landowners to identify thresholds or subjective beliefs above or below which certain actions, such as road removal, are preferable.
- Watershed management must depend significantly on beliefs about watershed processes rather than a complete understanding. The Team will be developing a Bayesian dynamic decision framework that allows managers to account for the important model and parameter uncertainties inherent in their tasks, as well as the option to reduce uncertainty by actively acquiring new information through data collection or experiments.
- Measurement of road surface erosion will serve the Team's immediate need for data to incorporate into the logging road management model. This data will also provide the opportunity to test the Watershed Erosion Prediction Project, a widely used erosion simulation model, against field observations.
- The detailed project-specific cost data that will be collected by the PSMFC over the coming months are expected to enhance the Team's efforts to estimate habitat restoration cost models.

Recreational and Commercial Fisheries

- Future development of commercial fishery participation models will focus on two applications of real options models. First, the models will be used to explore the possibility of contingent buybacks, in which fishermen can retain the option to re-enter fisheries once populations have recovered to target levels. Second, the models will be applied to license acquisition decisions and target species switching choices in multi-species fisheries.
- Further work on hierarchical production models will be directed toward inclusion of efficiency measures in discrete choice models of fishermen's area and target species choices. Such analysis could demonstrate, for example, the links between efficiency and location choices, providing a means of exploring the efficiency impacts of area closures and fishermen's likely responses to such closures.
- The Team is exploring the possibility of collaborating with UC-Berkeley graduate student James Hilger (NOAA Graduate Student Fellow in Economics) on applying some

of the fishery participation models developed by the Team to the CPFV fleet. Data collected in the 2002 economic survey of CPF V operators would be used in this project.

- The freshwater salmon/steelhead angler survey will be completed in early 2005. One of the first projects for the new FTE economist will be to analyze this data and develop models that demonstrate effects of changes in hatchery production (as reflected in bag limit changes) on fishing behavior and the economic value of the fishery.
- Once the nearshore groundfish logbook program gets beyond the pilot stage, the data will be used for spatial modeling and other management-relevant research applications.
- The Team is part of a technical working group that will be involved in a two-year effort to develop a science-based approach to integrating marine protected areas with fisheries management. This effort is being organized by the SCL and NOAA's National MPA Center.
- The Team is interested in participating in several upcoming projects being initiated by ST5 (nationwide protected species valuation survey, recreational harvest capacity)

Groundfish Analysis and Fishery Oceanography Team

Introduction

The Santa Cruz Laboratory has supported essential needs of the National Marine Fisheries Service (NMFS) and the Pacific Fishery Management Council (PFMC) for information on groundfish for over 25 years. Laboratory scientists have been members of the PFMC's Groundfish Management Team (GMT) every year since its inception in 1977, and have made many significant contributions in the form of stock assessments, development of new methods, evaluation of alternative management procedures, and collection and processing of important data on fisheries and resources. In view of the deteriorated condition of groundfish stocks along the U.S. west coast, the need for technical information on groundfish is critical, especially for the California component of the fishery.

Objectives

The goal of the Santa Cruz Laboratory's groundfish research programs is to support the information needs of the PFMC regarding Pacific coast groundfish stocks. Specific objectives are as follows:

- Resource Information: Collect and develop information that is useful in assessing and managing groundfish stocks, including both fishery-dependent and fishery-independent information (e.g., resource surveys), ecological and oceanographic studies.

- Resource Assessment and Policy Analysis: Conduct stock assessments that provide an understanding of the status and dynamics of groundfish stocks as a basis for harvest management decisions, and evaluate alternative harvest policies that have the potential to improve management performance. Develop new tools and analytical techniques.

- Dissemination: Disseminate information, research findings and associated advice to the fishery management community, including appropriate fishery management agencies, to the scientific community, and to the interested public.

- Service: Provide professional services (many of which fall in the above categories) at all levels, from Santa Cruz Laboratory support to participation in inter-agency, national and international working groups. Support advanced education in stock assessment and resource analysis, including the NMFS-UCSC CSTAR Program.

Research and Management Support Activities

Support for Fishery Management

Stock Assessments and Rebuilding Plans (since2002) –

Stock Assessments:		Rebuilding Analyses:	
Black rockfish	2003	Bocaccio	2002, 2003
Bocaccio	2002, 2003	Widow rockfish	2002, 2003
Widow rockfish	2003		
California sheephead	2004	ESA Biological Review: Bocaccio 2002	

- 2003/2005: Bocaccio was re-assessed following a problematic assessment in 2002. Although we knew that the 1999 year class was strong from anecdotal evidence, it was not yet recruited as of the 2002 assessment, leading to very restrictive groundfish management in California and a petition for ESA listing. The 1999 year class was prominent in the 2003 assessment, and estimated productivity was much higher than in the previous assessment. Bocaccio is scheduled for an "update" assessment in 2005.

- 2003/2005: Widow rockfish was assessed, and estimated surplus production was very near zero due to apparent lack of compensation (low steepness) in the stock-recruitment relationship. Rebuilding required severe catch restrictions. Widow rockfish is scheduled for an "update" assessment in 2005, but use of a new Bayesian prior on steepness (see below) may merit a full review.

- 2003: Black rockfish was assessed, and the stock appears to be in relatively healthy condition. A previous assessment in 2001 was completed, but was withdrawn after STAR Review when it was discovered that an agency had provided erroneous data.

- 2004: California sheephead is not a Council-managed species, but interacts with the southern California groundfish fishery. The 2004 assessment was done by an UCSC-CSTAR team and was funded by CDFG. Alec MacCall (unfunded) provided technical advice. Sheephead is a hermaphroditic species; although current fishing intensity is near 50% SPR for females, male SPR may be near 10%. The California Fish and Game Commission will address sheephead management in December in Monterey.

- 2004: A shortbelly rockfish assessment is currently in progress. Shortbelly rockfish is an unfished species, and the PFMC said it did not want an assessment. However, shortbelly is on the NMFS list of most important stocks to be assessed. We are using this assessment to test some new technical approaches.

- 2005: First-time gopher rockfish, kelp greenling and starry flounder assessments are planned. Gopher rockfish will be done jointly with Meisha Key (CDFG), and kelp greenling will be done jointly with Jason Cope (PhD student, University of Washington).
- 2005: A vermilion rockfish assessment will be conducted despite identification problems (John Hyde from La Jolla has reported two distinct genetic types).

Indirect Support for Groundfish Management

Groundfish Landings Database – Don Pearson works closely with the California Department of Fish and Game (CDFG) to coordinate port sampling efforts and to maintain the CALCOM database, which serves as the source of the data feeds provided to PacFIN by the State of California. The system provides port sampling biologists with Internet access to the database, so that monitoring data is entered directly in real time. Pearson recently developed new maximal "expansions" of landings and port sampling information that eliminate aggregate species and "unknown" categories. The new estimates are similar to the old estimates for the major species, but are much improved for the minor species, many of which will be assessed for the first time in 2005. PacFIN has indicated its intention to adopt the new species compositions associated with this expansion.

Through our liaison with CDFG (statistician Meisha Key spends part time at the SCL), we recently acquired a massive amount of historical California landings data on microfiche and original paper. These records include:

- A) Landings receipts 1969-present (75,000 pages, good quality)
- B) Landings receipts 1950-1968 from paper output (85,000 pages, poor quality)
- C) Species landings summaries 1931-1949 by 10-minute block origin (9,000 pages, poor)
- D) San Francisco area trawler catch and effort by block 1924-1939 (on paper, 3 boxes)

These data have immense value for stock assessment and habitat evaluation (e.g., EFH) purposes. We initiated data capture for item A (landings receipts, 1969-1980) because the good images allowed use of optical character recognition (OCR) and the work could be accomplished at reasonable cost. Apparently in response to our efforts, CDFG recently admitted already having those records available electronically, and has now agreed to transfer those records directly to PacFIN. Currently PacFIN has California landings back to 1981; this will extend the database back to 1969, and is being enthusiastically received by the assessment community.

The earlier data (item B, landings receipts 1950-1968) are especially valuable, and would extend the PacFIN database back to 1950. However, the poor image quality prevents use of OCR, so the data must be keyed by hand. We are trying to obtain cost estimates, which are likely to exceed $100K. Because the ESDIM "Data Rescue" program no longer exists, we are looking for alternative funding sources.

Otolith archive

Our archive now contains otoliths from nearly 400,000 fish, collected over the past 40 years. These samples are used for stock assessment (e.g., the several first-time assessments being conducted in 2005), and also for biological research. Recently, these archived otoliths have been used by academic researchers for age determinations of long-lived rockfish using

bomb radiocarbon. These archived otoliths may be our only hope for distinguishing between the newly discovered "species" of vermilion rockfish in historical landings, based on morphological or size-at-age differences, and perhaps genetic analysis of residual tissues.

Research for Fishery Management

Year 2004 was a non-assessment year under the PFMC's new two-year management cycle, allowing time for development of new tools and methods.

- EJ Dick developed a flexible computing package to do GLM analyses incorporating several delta-distributions, a variety of diagnostics, and jackknife estimation of precision. We have offered to contribute this package to the NMFS Stock Assessment Toolbox.
- EJ Dick developed an AIC-based diagnostic methodology for identifying appropriate probability distributions for use in GLM analyses. Diagnostics recommended in existing literature were shown to be insufficient.
- Xi He, Marc Mangel and Alec MacCall developed a "one-tailed prior" for stock-recruitment steepness, based on the evolutionary theory that low compensation leads to a high risk of extinction. Use of this unusual Bayesian prior was demonstrated to improve the performance of MCMC analyses. Andi Stephens (UCSC-CSTAR) and Alec MacCall developed a method for CPUE estimation, which draws inferences regarding fishing locations from the mix of species that is caught. This allows non-relevant fishing trips to be excluded from the analysis.
- Alec MacCall has developed statistical approaches to correct CPUE for changes in bag limits. He incorporated those methods in recent stock assessments and presented his methods at the Recreational CPUE Workshop in June.

Surveys and Ecological Research

The Groundfish Analysis Team has considerable experience in performing fishery-independent sea-surveys. Data collected from these cruises have been useful in the assessment and management of west coast groundfish and also in increasing our knowledge about the California Current ecosystem and its functioning.

Rockfish Recruitment Survey

Rockfish of the genus *Sebastes* exhibit extreme variability in recruitment (reproductive success), and the productivity of rockfish fisheries depends almost exclusively on the occurrence and influx of strong year-classes. Management of these fisheries therefore benefits from accurate information on impending recruitment. To meet that need, the Groundfish Analysis Team has used the NOAA R/V *David Starr Jordan* to conduct an annual survey of the distribution and abundance of pelagic juvenile rockfishes since 1983. The goal of the survey is to provide an information base for forecasting future recruitment to rockfish and other groundfish fisheries. Because rockfishes recruit at ages 2-6 years old, these surveys have the potential to provide a forecast of significant fluctuations in recruitment. A number of west coast groundfish stock assessments (e.g., Pacific whiting, widow rockfish, chilipepper, etc.) employ our pelagic juvenile index to estimate recruitment strength of year classes that are too young to appear in fishery catches, significantly improving the accuracy of assessment forecasts.

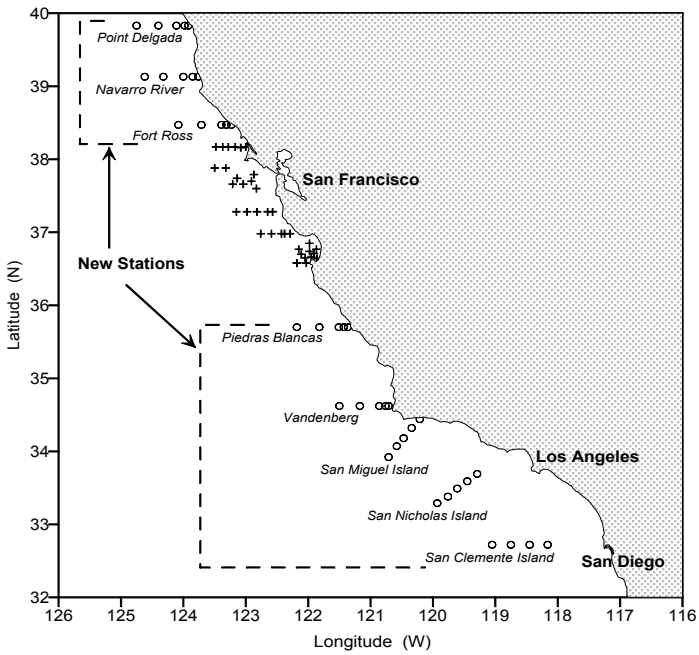

Figure 1 Station locations of the Santa Cruz Laboratory's annual pelagic juvenile rockfish midwater trawl survey. The survey was expanded to the north and south in 2004 with the addition of 39 new stations (circles).

In 2004 the geographic coverage of the pelagic juvenile rockfish mid-water trawl survey was expanded substantially, with the addition of new sample lines at San Clemente Island, San Nicolas Island, San Miguel Island, Vandenberg, Piedras Blancas, Fort Ross, Navarro River, and Point Delgada (Figure 1). This increased the effective latitudinal range of the survey from 180 to 800 km, representing a four-fold increase in coverage. The survey's expansion was made possible due to the SWFSC's allocation of additional shiptime (i.e., from 34 to 42 DAS) and changing from a design-based estimation scheme to a model-based GLM that includes year, station, and calendar date effects. The rationale for the shift was described in the 2002 program review document. In addition, for the last three years Groundfish Analysis staff has coordinated survey sampling efforts with the Pacific Whiting Conservation Cooperative, which recently initiated a very similar late-spring mid-water trawl survey off the coasts of Oregon and California. Their program is funded by the NWFSC with the goal of developing a pre-recruit index for use in the whiting stock assessment. With the expanded geographic coverage that was accomplished by the two surveys this year, it should be possible to develop coastwide groundfish pre-recruit indices. Moreover, results from an analysis of port-specific stock assessments that was recently completed by John Field and Steve Ralston, show broad spatial coherence in rockfish recruitment events along the US west coast. These findings will help to alleviate concerns about the more restricted spatial scale of the survey in prior years. Juvenile rockfish abundances were low in 2003, as is normal for El Nino conditions. In 2004 they rebounded to values that are generally above their long-term means (Figure 2). Catch rates of black, yellowtail, stripetail, canary, widow, and blue rockfish were notably high (note log-scale). In contrast, abundances of bocaccio, squarespot, and shortbelly rockfish in 2004 were not. An improvement in rockfish reproductive success, following the putative 1998-99-regime shift, and following the extended period of poor survival that occurred during the mid-1990s, is obvious. Results from the survey suggest that rebuilding of the overfished widow and canary rockfish stocks may occur more quickly than current management projections indicate.

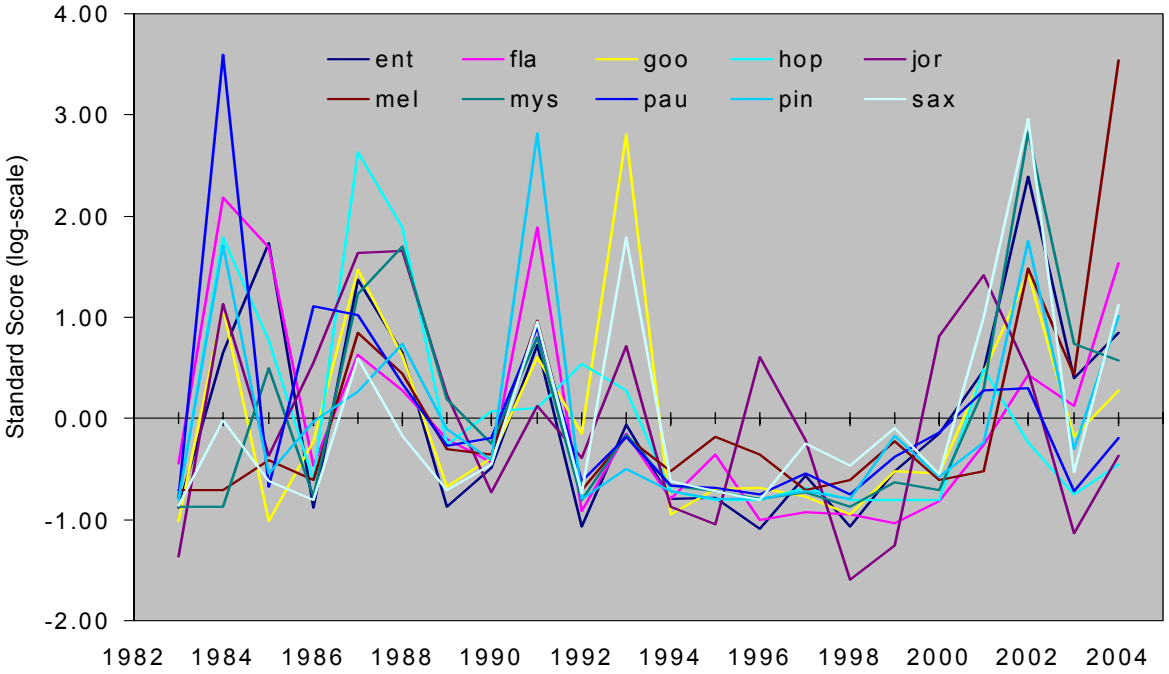

Figure 2 Time series of pelagic juvenile rockfish abundance in the Santa Cruz Laboratory midwater trawl survey (results presented here are unadjusted for interannual differences in age composition).

Rockfish Larval Production Survey

Following publication of the shortbelly rockfish larval production paper, described in the 2002 program review document, Steve Ralston is leading a study in cooperation with the FRD to estimate the spawning biomass of bocaccio in the southern California Bight. This study will utilize growth, maturity, and fecundity information data obtained from sampling female bocaccio at the Ensenada fish market, coupled with CalCOFI and CCA enhanced ichthyoplankton sampling of bocaccio larvae. Results of the analysis should compliment the stock assessment of bocaccio that will be conducted in the coming year. Preliminary results indicate that in southern California larger/older females release larvae at least twice during the spawning season.

Central California Cooperative Groundfish Ecology Survey

In an effort to obtain a comprehensive understanding of the central California groundfish community and groundfish ecology, Don Pearson has used SAIP funding to continue the groundfish ecology surveys that began in late 2001. Cooperative research funding of the survey has allowed full monthly coverage for three consecutive years. The survey utilizes chartered commercial trawl and longline vessels using standardized gear, and typically operates over a wide range of depths in an area off Davenport, not far from the Santa Cruz Laboratory. Recently, collections have expanded to other sites in the Monterey Bay area, where difficult to obtain specimens have been successfully sampled. The primary objective of the survey is to obtain detailed seasonal validation.

Some of the specific accomplishments of this program are:

- Logistics, methods and protocols for cooperative research aboard commercial fishing vessels have been developed and standardized.

- Extensive samples of age, growth, maturity and fecundity for several species, including those scheduled for stock assessments and also those that are too small to be landed commercially and too deep to be landed recreationally, have been collected.

- A paper comparing efficiency and accuracy of alternative length measurements was completed and submitted for publication.

- A paper on the life history of sand sole is in preparation.

- A paper on the life history of greenspotted rockfish is in preparation.

- A potentially serious problem was identified, wherein blackgill rockfish can easily be mistaken as darkblotched rockfish (an overfished stock) in fishery samples. We are photo documenting fish appearances as they are caught, and have developed reliable diagnostic characters for field use.

- Flag rockfish showed evidence of multiple spawning in 2004, but not in 2002 and 2003. Evidence for multiple spawning is now being tracked for several species of rockfish.

- Tagging of nearshore groundfish species has been continued and a research plan to deploy sonic-tags has been developed.

- A variety of elasmobranch specimens, especially skates, has been provided to Moss Landing Marine Laboratory.

- This program has also provided substantial public relations benefits to NMFS and the SCL through improved credibility with the local fishing community – a common complaint is that the fishery scientists do not spend enough time "on the water."

Other advances in ecosystem understanding

Partially in anticipation of the next re-authorization of the MSFCMA, the Groundfish Analysis Team is expanding its capability to address issues in ecosystem modeling and management. Some recent accomplishments are:

- John Field (formerly our FATE postdoc) and Steve Ralston developed location-specific estimates of annual recruitment for three species: chilipepper, widow and yellowtail rockfish. They were able to partition annual recruitment variance into local (28-49%) and synchronous large-scale (51-72%) components.

- John Field completed a PhD Dissertation titled "Application of ecosystem-based fishery management approaches in the northern California Current."

- Alec MacCall participated on a PICES FERRRS Study Group investigating "Fisheries and Ecosystem Responses to Recent Regime Shifts."

- Alec MacCall analyzed multivariate long-term patterns of variability in ocean conditions by integrating the likelihood response surface over all possible two-wavelet deterministic models. The result identifies new patterns of potential regime shifts in the northeastern Pacific. Results were presented to the PICES FERRRS Study Group, and are being prepared for publication.

- Xi He continues to work with coauthors at CSIRO, Tasmania, to complete and publish modeling studies of the sub Antarctic ecosystem.

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Presentations

- Steve Ralston made two presentations at the Larval Fish Conference, Aug. 20-22, Santa Cruz CA.
- Steve Ralston and John Field each made one presentation at the Fisheries and the Environment meeting, Sept. 22-23, Seattle WA.
- Alec MacCall and Steve Ralston each made a presentation at the Building Environmentally Explicit Stock Assessments (BEESA) Workshop, Oct. 29-31, Pacific Grove CA.
- Alec MacCall presented a seminar to CSTAR at UCSC, February 3, Santa Cruz CA.

- Alec MacCall participated in a PICES Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts, Feb. 9-11, Victoria, BC, Canada.
- Steve Ralston and John Field each made oral presentations, and Keith Sakuma presented two posters at the Western Groundfish Conference, Feb. 9-13, Victoria, BC, Canada.
- Steve Ralston chaired a PFMC groundfish EFH/EIS review, Feb. 23-25, Seattle WA.
- Edward Dick and Xi He presented talks at the NSAW, March 2-4, Newport RI.
- Steve Ralston made a presentation at the Fisherman/Scientist Forum, April 12, Moss Landing CA.
- Alec MacCall made a presentation at the PICES Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts, June 14-17, Seattle WA.
- Steve Ralston was a keynote speaker at the International Symposium on Otolith Research and Application, July 12-16, Townsville, QLD, Australia.
- Edward Dick made one presentation and Alec MacCall made two presentations to the PFMC Recreational CPUE workshop, June 29-30, Santa Cruz CA.
- Steve Ralston made four presentations, and Alec MacCall made three presentations to the PFMC Data Workshop, July 26-30, Seattle WA.
- Xi He presented a paper at the AFS meeting, Aug 23-27 Madison WI.

Committees and Service

- Ken Baltz is the SWFSC representative on the NOAA Fisheries Bottom Trawl Survey Working Group.
- Ken Baltz is a member of the Law Enforcement Consultants to the PFMC, representing US Coast Guard District 11.
- Ken Baltz is a member of the SCL Space Committee.
- Edward Dick is a member of the SCL Outreach Committee.
- John Field is a member of the National Center for Ecological Analysis and Synthesis Working Group Climate and Fisheries in North Pacific Ecosystems.
- Xi He is a member of the Pacific Fishery Management Council's Groundfish Management Team.
- Alec MacCall served on the California Sheephead Stock Assessment Team.
- Alec MacCall served as a rapporteur at the Building Environmentally Explicit Stock Assessments (BEESA) Workshop.
- Alec MacCall was a member of the convening committee, chaired a session and served as a rapporteur at the NSAW.
- Alec MacCall chaired the California Current subgroup of the PICES Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts.
- Alec MacCall served as a PSARC peer-reviewer of the 2004 British Columbia herring assessment.
- Alec MacCall is a co-PI (with Marc Mangel) of the NMFS-UCSC Center for Stock Assessment Research (CSTAR).
- Steve Ralston Chairs the Groundfish Subcommittee of the Pacific Fishery Management Council's Scientific and Statistical Committee.
- Steve Ralston chaired a committee reviewing bottomfish stock assessment methods for WPFMC and the Honolulu Laboratory.
- Keith Sakuma is a member of the RecFIN Statistical Subcommittee.

- Keith Sakuma is member of the SCL IT Committee.

Future Research Directions

Stock assessments
We expect to complete at least six stock assessments for the PFMC in year 2005: bocaccio, widow rockfish, gopher rockfish, vermillion rockfish, starry flounder and kelp greenling. We will independently conduct a shortbelly rockfish assessment. This is an ambitious schedule, and will occupy our personnel for most of the year.

Database management
We will assist CDFG in transferring improved species composition information from CALCOM to PacFIN. We will continue to seek support for capture of the historical California landings data currently residing on microfiche.

Survey
The extended pattern of juvenile rockfish midwater trawl stations will be occupied for a second year, and we will begin to build the capability of assessing relative juvenile abundance on a much larger geographic scale. Staffing of the cruise may conflict with the stock assessment schedule.

The cooperative Groundfish Ecology Survey may monitor species shifting in reponse to the Kelvin wave associated with the predicted El Nino.

Cooperative research and fish tagging
Acoustic tagging of nearshore rockfish is planned for the Groundfish Ecology Surveys, which will contribute to understanding the mobility of nearshore rockfish stocks. We will initiate an industry-based survey of cabezon and greenling in the Avila-Morro Bay area, working with commercial fishermen. A planning meeting is scheduled for late September, 2004, but current thinking is to minimize mortality associated with the survey and to emphasize mark-recapture, taking full benefit of the live-fish technology possessed by the fishermen.

CSTAR training and research
The NMFS-USCS Center for Stock Assessment Research will continue an active program of graduate education in quantitative fisheries biology. Also, Alec MacCall and Marc Mangel were awarded a NMFS "Ecosystem Decision Support Tools" grant of $100K for one year to conduct a study titled "Ecosystem attributes and adaptive approaches during stock rebuilding."

ECOLOGY BRANCH

The Ecology Branch conducts basic and applied research to increase understanding of the relationships between fishes and their environment, including distribution and abundance patterns, factors influencing growth and survival, habitat relationships, community structure, and molecular identification of stocks. Results of the branch's groundfish research are directly relevant to mandates of the Magnuson-Stevens Fisheries Conservation and Management Act to improve understanding of life histories and relationships of economically valuable species with their environment, thereby improving the capacity to develop sustainable harvest strategies. Several projects are directly focused on designation of Essential Fish Habitat for different life stages of rockfishes. Results of the branch's research with salmonids are directly relevant to the Endangered Species Act by providing new information on population interrelationships at the molecular level, early life history patterns, physiological ecology during seaward migration, and interactions of wild and hatchery reared fish. Research results are provided to fishery managers and the public via direct communication, reports, presentations, and peer-reviewed scientific publications. The Branch is comprised of four research teams. The Salmon Ocean and Estuarine Ecology Team focuses on basic ecology and physiology of coho, chinook, and steelhead, and the influences of estuarine and marine conditions on interannual variability of stock status. The Molecular Ecology Team focuses on population structure and conservation genetics of ESA-listed salmonid populations. The Habitat Ecology Team identifies and describes essential fish habitat for groundfish species; in particular, those that are managed and overfished, and conducts research in cooperation with NOAA's MPA Science Institute on siting, evaluation and implementation of Marine Protected Areas in California. The Early Life History Team conducts field and laboratory experimental research examining factors that affect survival in larval and early juvenile stages of salmonids and groundfish.

General objectives of the branch are:

- Conduct scientifically sound research with immediate application to management needs and long-term application to improved understanding of basic ecological relationships of economically valuable fishes with their environment.

- Provide timely dissemination of research results through multiple means of communication, with emphasis on peer-reviewed publication in scientific journals.

Salmon Ecology Team

Introduction

Eleven of thirteen salmonid Evolutionarily Significant Units (ESUs) in California are listed, or candidates for listing, by the U. S. Endangered Species Act (ESA). Persistence of chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*) populations from California's Central Valley and coastal streams is challenged by anthropogenic activities and periodic natural perturbations. Although freshwater habitat loss and degradation contribute to population declines, estuarine and ocean conditions apparently play a major role in the interannual variability in salmon abundance, especially during the first months after exiting freshwater. Climatic and oceanographic forcing factors, affecting scales ranging

from seasonal localized habitats to interdecadal ocean-basins, modulate environmental conditions that, in turn, affect marine productivity. Productivity and the physical environment influence salmon growth, development, and survival

Recovery and management of California's salmonids requires greater knowledge of the ecological processes that influence salmon populations. The need for greater knowledge of growth, development, survival, and the environmental variables that are beneficial or detrimental to these processes is particularly critical for early life stages during their residence in estuaries and in the first year of ocean life, when mortality rates can be quite high. The need for basic biological data and the influences of environmental factors on survival and health have been identified as high priority research needs by the PFMC (Research and Data Needs 1998-2000, PFMC, September 1998) as well as the scientific community (Estuarine and Ocean Survival of Northeastern Pacific Salmon, Proceedings of the Workshop, April 1997; NMFS Estuarine and Ocean Salmon Strategic Research Plan, April 1998). The Salmon Ecology Team conducts research-addressing variability among salmon populations and their responses to natural and human-related environmental factors. Information from our studies will improve understanding of environmental interactions and ecological adaptations of California's salmon stocks, which are at the southernmost end of the species' distributions, and aid in their recovery from ESA listing.

Objectives

- Determine the physiological ecology of juvenile salmon in estuaries and the coastal ocean
- Determine natal sources, spatial structure, and migration history of chinook salmon from the Central Valley
- Determine life history variability and interactions between wild and hatchery salmonids
- Establish and maintain captive broodstock of southern coho salmon to aid in the recovery and persistence of the species at the southern margin of its distribution

Research and Management Support Activities

Physiological Ecology of Juvenile Chinook Salmon in the San Francisco Estuary and Coastal Ocean

Chinook salmon populations from California's Central Valley have declined in recent decades. Although habitat loss above dams and water diversions have clearly adversely impacted Central Valley salmon, the contribution of environmental conditions in San Francisco Estuary and the coastal ocean is unknown. Because San Francisco Estuary, the southernmost estuary used by chinook salmon, is such a highly urbanized, industrialized, and agricultural ecosystem, estuarine nursery functions that prepare juvenile salmon for the ocean phase of their life cycle could be diminished. Further, once in the coastal ocean during the critical early period, spatial and temporal variations in oceanographic conditions may modulate growth, survival, and thus year-class strength. Although some data exist on aspects of juvenile salmon ocean and estuarine ecology, they are from the Pacific Northwest. In fact, information derived from northerly populations often form the basis for management decisions in California. Differences in environmental conditions, genetic traits, and physiological adaptations of California stocks likely require data specific to California salmon to effectively recover and manage them. In 1995 we initiated a study of juvenile chinook salmon as they emigrate through the San Francisco Estuary,

and expanded the study to include the coastal ocean in 1998.

The goal of this study is to increase knowledge and understanding of juvenile chinook salmon physiological ecology in the San Francisco Estuary and the coastal ocean. Specific objectives are to determine relative abundance, distribution, residence time, growth, energy dynamics, and feeding, and the influences of environmental and oceanographic factors on these processes.

Juvenile salmon are collected by trawl in the San Francisco Estuary in May and June, the primary emigration period. In the coastal ocean, stations associated with oceanographic features (eddies, upwelling centers, river plumes, jets) and along latitudinal transects on the shelf are visited up to three times each year: following migration through the estuary (June-July), after a few months in the ocean (August-October), and at the end of winter season (February-March). At each station, salmon are collected by 264 Nordic Rope Trawl towed at the surface, and stratified plankton, neuston, and chlorophyll samples and CTD data are acquired. In the laboratory, fish are measured, weighed, and tissues are removed for further analyses. Otoliths are analyzed for age and growth, stomach contents are used to determine prey selection and feeding intensity, and tissues are analyzed for protein and lipid class composition.

Results to date reveal a relatively consistent pattern of estuarine usage. Juvenile salmon enter San Francisco Estuary at about 4.5 months old, and spend about a month transiting the estuary. While in estuary, they exhibit limited growth (0-0.28 mm/d FL; -0.2 - +0.8 g/d wt) and declining condition (K factor). Energy (lipid) dynamics vary year-to-year and among locations, but in general energy reserves decline in the lower estuary. Smoltification (assayed by gill Na^+,K^+-ATPase activity), an energy depleting and growth restricting process, is essentially complete when juveniles enter the estuary. Prey selection changes from insects and amphipods in the upper estuary to include larval fish in the lower estuary. Principal component analysis reveals that measures of growth and energy accumulation are positively related to residence time and zooplankton abundance. These results suggest that juvenile chinook salmon have little estuarine dependency in San Francisco Estuary, expediting emigration to the coastal ocean with its high biological productivity and increased survival potential.

After ocean entry, most subyearling chinook salmon remain in the Gulf of the Farallones, but there is a distribution towards the north on the continental shelf, a process that increases into the fall. Three years of surveys revealed no evidence of extended southward movement by subyearling fish. Once in the ocean, greater feeding and catabolism of lipid reserves accelerate growth and K factor condition improves. Young chinook prey primarily on small fish, decapod and euphausiid early life stages, and amphipods. An interesting early result of our study is that during early marine residence subyearling chinook salmon grew faster during the 1998 El Niño than the 1999 La Niña.

Determining Natal Sources, Spatial Structure and Migration History of Chinook Salmon

Knowledge of the relative contributions of natal tributaries and hatcheries to the structure and dynamics of regional stocks is central to the sound management and conservation of anadromous species, but has been unattainable due to our inability to track the origin and

movement of individuals. Current use of coded wire tags provides limited insight into the role of individual natal sources to chinook salmon population dynamics due to small numbers of tagged fish and even fewer recoveries. Furthermore, this tagging technique provides no method to explicitly monitor population trends of wild populations or reconstruct fish movement into different habitats to elucidate the role of habitat in determining which individuals successfully enter the ocean fishery.

From juveniles collected at hatcheries and natal streams, and adults collected in the ocean fishery, Rachel Barnett-Johnson's dissertation research shows that otolith microstructure and geochemical composition of otoliths provide discrete tags for determining the production source, individual hatchery, and/or stream-of-origin for adult chinook salmon. Preliminary data reveal that hatchery and wild individuals can be classified 90% correctly based on differences in otolith microstructure formed during early growth. Sr isotopic ratios ($^{87}Sr/^{86}Sr$), unique to each major salmon-producing stream in the Central Valley, and therefore distinct among juveniles from different sources, are recoverable in otoliths from adults captured in the ocean fishery (Figure 1). This geochemical variation in otoliths is due to the underlying rock type and age in watersheds of the Central Valley, which produce a gradient in $^{87}Sr/^{86}Sr$ for salmon spawning rivers with low $^{87}Sr/^{86}Sr$ in Sacramento River tributaries and high $^{87}Sr/^{86}Sr$ in San Joaquin tributaries. In addition, distinct $^{87}Sr/^{86}Sr$ occur during five life stages, including prefeeding, natal source rearing, smolt outmigration, estuarine and ocean residence, and thus, can be used to reconstruct movement in different habitats. Our ability to correctly identify the origin of adults in ocean fisheries and reconstruct their environmental histories demonstrates that this technique has the potential to link juvenile and adult life histories and elucidate influences of specific habitats to subsequent growth and perhaps survival in a broad range of fishes.

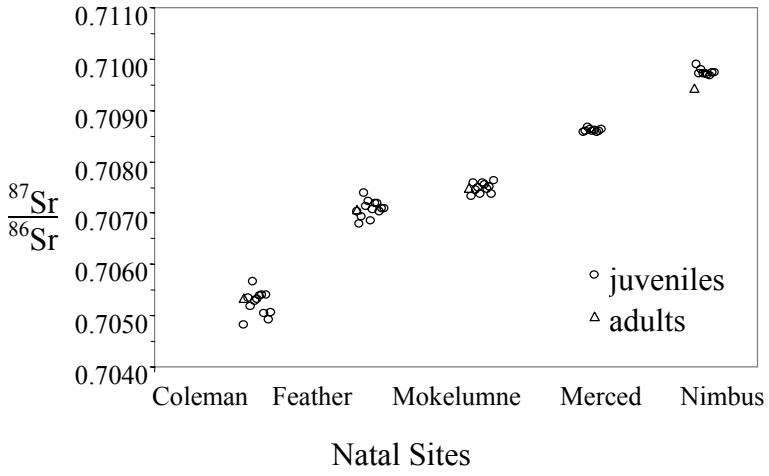

Figure 1 $^{87}Sr/^{86}Sr$ ratios in juvenile portion of otoliths from juvenile (○) and adult (▲) chinook salmon from the five California Central Valley hatcheries. All sites are significantly different from one another (Tukey's HSD, $P<0.001$). All tagged adults are correctly classified to natal origin.

Physiological Ecology of Salmonids in Small Central California Estuaries

It has been hypothesized that the small estuaries along the California coast are important rearing areas for steelhead and salmon, and that the open or closed state of the estuaries may affect the fish's development and ultimate survival. This project is investigating salmonid utilization of some small estuaries by looking at population abundance, growth, feeding, and metabolic status of juvenile fish throughout the year while these estuaries are both open to the

ocean and closed by sandbars. The focus is on five small estuaries that range across approximately 80 miles of California's central coast (~ 2° latitude): Redwood Creek (Marin County); Gazos Creek (San Mateo County); Scott Creek, Soquel Creek, and Aptos Creek (Santa Cruz County). All have steelhead populations, and all except Soquel and Aptos have coho salmon, although these creeks historically supported coho. These creeks are at the extreme southern extent of the coho range. Previous studies have shown most abundant numbers of salmonids in the estuaries between April and September. During this time, the water quality may change dramatically due to increases in temperature, decreased water flow, and sandbar formation. How this affects juvenile salmonids is unknown. Assessment of the physiological ecology of juvenile salmonids in these estuaries will provide information necessary for effective protection of these endangered species and the management of their habitats.

The goal of this study is to determine growth and physiological status of juvenile salmonids, and their utilization of small estuaries across time. Specific interests include how the open/closed state of the estuary affects the fish, and whether there are similar patterns among the five creeks. Patterns of relative abundance and estuary utilization are determined with monthly seine surveys. Fish are measured and weighed on site, then released. All fish over 65mm are implanted with a PIT tag so that individuals can be followed throughout the course of a season, year or numerous years, to record individual growth rates. Temperature preferences of fish are being determined by fitting fish with archival temperature tags. These small tags collect data every minute for a day or every five minutes for a week. By comparing these data to temperature loggers throughout the stream we can elucidate fish movements and temperature preferences within the estuaries. In concert with fish study, environmental data (temperature, salinity, pH, [O_2], turbidity, flow (in/out) and open/closed state) at each estuary are collected monthly (and in some cases constantly). Scott Creek estuary is the focus of a GIS-based in-depth characterization of annual hydrologic dynamics and water quality.

This project started in 2003. As the study ramps up, additional analyses will be incorporated, including feeding ecology, metabolic rates (respirometry, enzyme activities), and energy (lipid) dynamics. To date, over 1500 fish have been evaluated in the five estuaries. In 2003, small temperature loggers (17) were deployed on juvenile steelhead in Scott Creek estuary during the closed state in the fall. Data from four recovered tags revealed that juvenile steelhead prefer the coolest water available regardless of water depth, even though higher temperature waters were well within the species' physiological range. Growth rates of steelhead in our suite of estuaries vary by a factor of four, ranging from < 1 mm/d to > 4mm/d, with some of the highest rates found in Aptos Creek, an human-impacted, urbanized estuary.

Comparative Life History Studies on Hatchery and Wild Salmonids

We are currently studying basic life history traits of coho salmon and steelhead and how these traits may be affected by artificial propagation and environmental challenges associated with living at the southern end of their distributions. The study site, Scott Creek and its tributaries, composes a small coastal watershed north of Santa Cruz and is inhabited by steelhead and the southernmost population of coho salmon. Both stocks are listed as threatened under the ESA and are supplemented by a small hatchery. Our long-term objectives are to better understand how local population dynamics and hatchery influences assess carrying capacity of local watersheds and the effects of fluctuating environmental conditions on ocean and stream

survival.

We first investigated the ecological impacts artificial propagation practices might be having on wild populations. We monitored comparative development and stream distributions of hatchery and wild fish and evaluated hatchery production protocols. We found that little opportunity existed for competition between hatchery and wild juveniles, as hatchery fish were released at the smolt stage and departed the watershed within weeks of planting. Only minor differences were observed in adult spawning behavior, and no differences in size or age of returning adults were observed.

We are currently analyzing data pertaining to how local populations have adapted to southern environmental conditions. Whereas northern salmonids are challenged by harsh winters and grow primarily during the summer, it appears that fish in southern populations grow primarily during the mild coastal California winters. Low stream flows and warm temperatures in the upper tributaries appear to limit growth during the summer months. However, summer flows often become so low that estuaries become closed off from the ocean, forming lagoons rich in prey that stimulate rapid growth. The integrity of these lagoons may be critical to survival. Our data suggest that juvenile steelhead, seawater ready during the spring, appear to desmoltify during the summer and may be less able to withstand the challenges of ocean hyper tonicity if required to enter seawater during that time.

We have been investigating the relationship between resident rainbow trout and anadromous steelhead, an issue central to determining the status of steelhead populations. Genetic analysis done in collaboration with the Santa Cruz Molecular Ecology Team has revealed that fish pursuing resident life history trajectories above and below anadromy barriers are genetically identical. In addition while sharing common local ancestry; they are genetically distinct from adult steelhead. Residents are the same age or older than steelhead smolts and do not experience changes in osmoregulatory ability during the spring downstream migration. However, residents have been observed spawning with steelhead. Further, tagged residents from above anadromy barriers have been captured in downstream migrant traps just above the estuary, suggesting that residents contribute to and possibly help maintain anadromous populations.

With the installation of a temporary weir and instream PIT tag readers, our efforts are now being directed at addressing questions regarding relative reproductive success and rates of hybridization among hatchery steelhead, wild steelhead, and resident fish; parental influence on offspring life history; straying rates; measures of smolt production; ocean growth and survival; and movements at sea and in the watershed. The results of this work will provide managers greater understanding of differences between wild and hatchery fish, and the range of life history variations, which provide information necessary to rebuild central California salmonid populations to levels that are resilient to environmental and anthropogenic influences.

Importance of estuarine habitat to steelhead growth and survival in a central California stream

Determination of critical habitats for steelhead listed under the ESA is becoming increasingly important as populations remain threatened. We are investigating the significance of estuarine habitat and how its use by juvenile steelhead may contribute to increased growth and survival at sea. Scott Creek, a small watershed in central California, contains an estuary that

some juvenile steelhead utilize before heading to sea. Growth rates of steelhead in the estuary are 4-5 times those in more upstream waters, indicating that fish of the same age from both habitats may be drastically different sizes upon ocean entry. From scale analysis of returning adults, back-calculation of size at ocean entry supports the hypothesis that larger fish have higher survival at sea than do smaller fish from this watershed (Figure 2). Trapping and tagging of downstream migrants from the upper watershed and sampling of the estuary indicate many, but not all, migrants spend the summer and fall in the estuary and their mean length at ocean entry in late fall has almost doubled since entering the estuary in the spring.

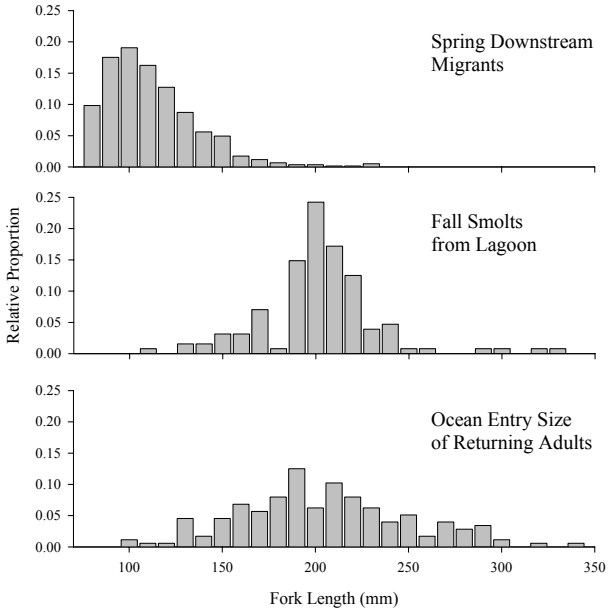

Figure 2 Steelhead size distributions of downstream migrants at estuary entry, while in the lagoon in the fall, and at ocean entry for surviving adults. Data from 2002-2004.

To quantify the growth from each habitat we are currently monitoring the size of smolts reared in the upper watershed during their spring downstream migration, as well as the size of estuarine-reared steelhead at their ocean entry in the fall. In addition, we are conducting micro chemical analysis of scales from both returning adult and juvenile steelhead using laser ablation ICP-MS. Scales are burned from the focus (youngest) to the outer edge (oldest) portion to determine whether fish movement into waters of varying chemistry is recorded by trace element incorporation in scales. Estuarine water with its marine influence may impart a chemical signature different from that of upstream waters, and the time spend in each habitat can be identified. This study will clarify the influence of growth in estuaries on central California steelhead ocean survival.

Southern Coho Salmon Captive Broodstock

Coho salmon populations are declining throughout their range on the West Coast. Of six ESUs, three are listed as threatened under the ESA. Populations south of the Golden Gate are at the highest risk of extinction. In fact, the ESU is currently being reevaluated for downgrading to endangered. Only two streams south of the Golden Gate, Scott and Waddell Creeks, have significant runs of coho salmon. And in these systems, only one of three year-class lineages has significant numbers. The stocks would be in even greater jeopardy without supplementation by artificial propagation. Since the mid-1970s, a hatchery operated by the Monterey Bay Salmon and Trout Project (MBSTP) on a tributary of Scott Creek has enhanced Scott and Waddell Creeks with progeny from coho salmon trapped in Scott Creek and spawned at the hatchery.

In recent years, the collection of broodstock has become increasingly difficult due to poor adult returns. The causes are unknown, but are probably related to poor ocean survival and

premature flushing of young fish from freshwater habitats by strong storms. In 1996, a team of NMFS, CDFG, U.S. Fish and Wildlife Service, and academic scientists recommended a recovery plan that included artificial propagation and reintroductions with a captive broodstock component. They also recommended research and monitoring of southern coho life history traits, genetics, ecological requirements, and population dynamics.

The goal of the captive broodstock program is to ensure the continuation and recovery of coho salmon at the southern margin of their distribution. Specific objectives are to: (1) provide gametes, which preserve and increase genetic diversity, to the MBSTP hatchery for the continued production and enhancement of indigenous coho salmon; (2) provide mature adults for spawning in suitable streams south of the Golden Gate; and (3) increase knowledge and understanding of the physiological, ecological, and genetic attributes of southern coho salmon by use of broodstock progeny for research.

In 2002, the first year of the project, progeny of wild coho salmon caught in Scott Creek were artificially propagated at the Kingfisher Flat Hatchery. After genetic analysis (12 microsatellite loci) of 500 juveniles, 150 fish with maximum genetic diversity were separated into two groups after smoltification. One group (100) was placed in a seawater facility at the NMFS Santa Cruz Laboratory and a secondary group (50) was maintained in a freshwater facility at the Kingfisher Flat Hatchery. This winter, the 2002-year class will become reproductively mature. Their maturity and sex will be assessed using ultrasound. Two weeks prior to spawning, fish will be implanted with synthetic salmon gonadotropin releasing hormone to promote reproductive synchrony. Gametes from captive broodstock will be used to supplement spawning of naturally returning salmon to the extent necessary. The hatchery is permitted to spawn 30 females and 45 male fish. Broodstock exceeding hatchery needs will be introduced into suitable streams south of the Golden Gate, i.e., those with appropriate habitat and no or low numbers of naturally returning coho salmon.

Once the captive broodstock program has demonstrated success, we intend to use a limited number of progeny for laboratory experimentation to determine physiological and ecological performance and adaptations to environmental conditions that exist at the southern end of the distribution.

The results of the captive broodstock program will be evaluated at the hatchery and in the field. In the hatchery, fertilization rate, growth rate, and survival of young from broodstock gametes will be recorded and compared with values from hatchery-spawned wild fish. A temporary weir installed in Scott Creek will allow estimates of growth and survival of returning broodstock progeny, since they will be fin-clipped and a subset will receive PIT tags. The captive broodstock program will run for nine years. When southern coho salmon stocks in Scott and Waddell Creeks are self-sustaining, or after three generations of each of three year-class lineages, whichever occurs first, the program will be discontinued.

Currently, coho from all three year-class lineages are being held as broodstock. For the 2002-year class, there are 76 in the seawater facility at the Santa Cruz Laboratory (SCL) and 49 in fresh water at the hatchery. No adult coho were found in surveys of Scott Creek during 2003 and 2004, thus no juveniles were propagated for the broodstock. However, some natural

reproduction occurred within Scott Creek and wild juveniles were collected for broodstock. We have 65 in the 2003 broodstock; 38 at SCL and 27 at the hatchery. Fifty-eight parr from the 2004 are also being maintained at the hatchery.

Accomplishments

Publications

- Barnett-Johnson, R.C., Ramos, F.C., MacFarlane, R.B., and C.B. Grimes. Identifying the natal origin and migration history of adult salmon using Sr isotopes in otoliths by laser ablation MC-ICPMS. Canadian Journal of Fisheries and Aquatic Sciences (In review)
- MacFarlane, R.B., S. Ralston, C. Royer, and E.C. Norton. Juvenile chinook salmon (Oncorhynchus tshawytscha) growth on the central California coast during the 1998 El Nino and 1999 La Nina. Fisheries Oceanography (In press)
- Hayes, S.A., M.H. Bond, C.V. Hanson, and R.B. MacFarlane. Interactions between endangered wild and hatchery salmonids; can the pitfalls of artificial propagation be avoided in a small coastal stream? Journal of Fish Biology (In press)
- Barnett-Johnson, R.C. 2004. Sources of Salmon. In PISCO Coastal Connections: 3:13.
- Lindley, S.T., R. Schick, B.P. May, J.J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2004. Population structure of threatened and endangered Chinook salmon ESUs in California's Central Valley basin. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-370, 66p.
- MacFarlane, R.B., S. Ralston, C. Royer, and E.C. Norton. 2002. Influences of the 1997-1998 El Nino and 1999 La Nina on juvenile chinook salmon in the Gulf of the Farallones. PICES Scientific Report No. 20:25-29.
- MacFarlane, R.B. and E.C. Norton. 2002. Physiological ecology of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and the Gulf of the Farallones, California. Fishery Bulletin 100:244-257.

Presentations

- Third International Symposium on Fish Otolith Research and Application, Townsville, Australia, 2004 (Barnett-Johnson, Ramos, Grimes, MacFarlane 2 presentations).
- American Fisheries Society, Madison, WI, 2004 (Wells and Grimes 2 presentations).
- Fisheries Society of the British Isles, Nature and Culture: Comparative Biology and Interactions of Wild and Farmed Fish Symposium, London, 2004 (Hayes, Bond, Hanson, MacFarlane)
- Keck Symposium for Multi-collector Mass Spectrometry, Santa Cruz, CA, 2004 (Barnett-Johnson, Ramos, Grimes, MacFarlane)
- San Lorenzo Lagoon Workshop, Santa Cruz, CA, 2004 (Freund)
- Santa Lucia Gradient Study, Santa Cruz, CA, 2004 (MacFarlane)
- Recovery Science Review Panel, Santa Cruz, CA, 2004 (MacFarlane, Barnett-Johnson: 2 presentations)
- Monterey Bay National Marine Sanctuary Symposium, Monterey, CA, 2004 (Ammann, Bond, Freund, Hanson, Hayes, MacFarlane, Wells: 3 presentations)

- Western Division of the American Fisheries Society, San Diego, CA, 2003 (Hayes, Hanson, Bond, MacFarlane)
- Center for Reproduction of Endangered Species, San Diego Zoo, San Diego, CA, 2004 (Grimes and Barnett-Johnson: 2 presentations)
- 27th Annual Larval Fish Conference, Santa Cruz, CA, 2003 (Barnett-Johnson, Grimes, Royer, Ammann: 2 presentations)
- CalFed Emergency Water Account Workshop, Sacramento, CA, 2003 (MacFarlane)
- 5th Annual Salmon Ocean Ecology Conference, Newport, OR, 2003 (MacFarlane)
- Monterey Bay National Marine Sanctuary Symposium, Monterey, CA, 2003 (Norton)
- American Fisheries Society, Quebec City, PQ, 2003 (Wells and Grimes: 3 presentations)
- 4th Annual Salmon Ocean Ecology Conference, Santa Cruz, CA, 2002 (MacFarlane, Barnett-Johnson, Norton: 3 presentations)
- 26th Annual Larval Fish Conference, Bergen, Norway, 2002 (MacFarlane, Norton, Alonzo)

Committees and Service

- California Ocean Current Monitoring Program [Proposition 40] advisor (MacFarlane)
- Central Valley Technical Recovery Team (MacFarlane) Technical Oversight Committee, Monterey Bay Salmon & Trout Project (MacFarlane, Hayes, Sturm)
- Technical Advisor, Comparative Lagoon Ecological Assessment Program, Santa Cruz County, (MacFarlane, Freund)
- UCSC graduate student committees (MacFarlane)
- Scotts Creek Watershed Council advisor (Freund, Hayes)
- Census for Marine Life advisor (MacFarlane)
- Public meeting briefing, City and County of Santa Cruz, Estuary/lagoon salmonid studies (Freund)
- Santa Cruz County Conservation District briefing (MacFarlane)
- Training on otolith preparation, image analysis, data collection (Barnett-Johnson) to:
  UCSC undergraduate thesis students (5 students)
  CDFG training program LaGrange, California, (25 biologists)
  CDFG Merced River Hatchery Santa Cruz, California, (5 biologists)
  DWR thermal marking project Oroville, California (3 biologists)
- Santa Cruz County Science Fair, judge for junior division in physiology (Barnett-Johnson)
- NOAA Fisheries, Santa Cruz Lab Outreach Committee (Freund)
- NOAA Fisheries, SWR, EEOAC (Norton)
- Pescadero Watershed Council advisor (Freund, Hayes)
- Salmon and Trout Education Program, teacher training (Hayes)

Extramural Research Support

- California Coastal Salmon Restoration Program, 2001-2003 ($139K)

Future Research Directions

- Continue coastal juvenile salmon survey to complete 5-year database assessing relationship between salmon development and oceanographic conditions in survey area

(Pt. San Pedro [San Francisco]– Pt. Arena)

- Develop acoustic tagging – tracking program of juvenile chinook salmon and steelhead through Sacramento River to the Golden Gate to determine migration rate, habitat usage, and survival
- Develop acoustic and archival tagging program for coastal steelhead and coho salmon to determine estuarine and ocean habitat usage
- Conduct experiments studying physiological performance and metabolic efficiency among populations of steelhead and coho salmon of differing origins (streams, hatchery/wild) under differing environmental conditions, including determination of adaptations unique to southern end of species' distributions
- Determine the relationship between habitat quality and size/age of smoltification in coastal steelhead
- Determine relative reproductive success among hatchery steelhead, wild steelhead, and resident rainbow trout
- Determine interannual variability of ocean growth and survival of wild and hatchery produced steelhead and coho salmon
- Enhance weak year classes of southern coho salmon by accelerating growth and maturation of some captive broodstock

Molecular Ecology and Genetics Team

Introduction

The Molecular Ecology Team studies questions in ecology, evolution, conservation and management of marine biological systems in California using molecular and population genetic methods. Much of this work involves salmonids and is in collaboration with other Teams in the Santa Cruz Laboratory as well as biologists from universities and other agencies. The work of the Molecular Ecology Team supports both the protected resource and sustainable fishery objectives of NOAA Fisheries.

Molecular genetic data are now a well-established tool for biological investigation, including conservation biology and fishery management. In addition, an understanding of the hereditary basis of phenotypic and life history variation is central to predicting the effects of various management practices, such as fishery size limits and hatchery breeding techniques. Specifically, the use of molecular genetic data allows delineation of population structure, estimation of population size and trajectory, estimation of pedigree relationship between individuals, identification of individuals to population of origin and evaluation of many other parameters in population biology. The diverse projects of the Molecular Ecology Team include providing comprehensive and data-rich evaluations of genetic population structure for salmon and trout, the development of new methods for estimating population size and relative changes in size, the description of structure and variation of functional genes in marine and anadromous fishes, investigation of the heritable basis of migratory and reproductive behavior in steelhead trout, data-driven support of conservation and fishery management decision making and archiving tissue samples for future studies of population genetics of marine and anadromous fishes.

Objectives

- Elucidate genetic population structure for anadromous and marine fishes
- Improve stock assessments and recovery planning through use of genetic data
- Develop new methods for estimation of size and other population parameters
- Estimate stock-specific fishery exploitation rates through genetic identification
- Employ genetic methods to understand reproduction and recruitment of fishes
- Understand the heritable basis of phenotypic and life history variation in fishes
- Inform management and conservation of marine and anadromous fish and fisheries
- Archive genetic material of anadromous and marine fishes for future research.

Research and Management Support Activities

Population Genetic Structure

Salmonids

In California, all but four of the fourteen evolutionarily significant units (ESUs) of anadromous salmonid are listed as threatened or endangered under the US and California Endangered Species Acts. We are collecting multilocus microsatellite genotypes and data from variable DNA sequences to study population structure of steelhead, chinook salmon and coho salmon in the coastal and inland rivers of California. We are examining the magnitude and distribution of population genetic variation at multiple geographic scales, including stream reaches within a river, different tributaries of larger river systems, different rivers and, finally, different ESUs. We are also investigating the temporal component of population structure by estimating population genetic differences between cohorts and generations of salmon and trout populations. This is particularly important with coho salmon, which follow a strict 3-year life cycle, and have the potential for differentiation between broodyears. This work is in collaboration with the Salmon Population Analysis and Salmon Ecology Teams of the Santa Cruz Laboratory and with biologists from the California Dept. of Fish and Game, the US Fish and Wildlife Service, the University of California, and Sonoma and Humboldt State Universities.

Steelhead Trout

Steelhead trout are the most widespread anadromous salmonid in California and are found in almost every stream or river with consistent access to the sea. We are investigating population structure of steelhead at many different scales. The first effort, which is largely complete, examined populations from 40 river systems and 60 sites covering almost the entire range of the species in coastal California using data from 18 highly variable microsatellite loci. In this project approximately 3000 fish were genotyped and all the samples consist entirely of individuals from the same year class, which were sampled using the same standardized stream sampling protocol. This work was initiated to fill a large gap in understanding of population structure by the North-Central California Coast Technical Recovery Team. Sampling for the project was coordinated and largely carried out by the Salmon Population Analysis Team.

The work has revealed a pattern of isolation by distance in coastal steelhead populations, with genetic distance, and therefore rate of migration, between populations dependent upon their geographic distance. Genetic distance was also found to be approximately half as large between tributaries of large rivers as between streams with separate ocean entrance. It has also

demonstrated a high degree of genetic differentiation between steelhead populations which provides the ability to use these genetic data to assign individuals to river system with greater than 90% accuracy. In many cases, this level of accuracy was achieved even between different tributaries of the same river. This finding will allow accurate identification of individuals to river system of origin in fishery, ecological or forensic investigations.

We are currently extending this work to include the southern California steelhead ESU and denser sampling of the three of the four largest coastal river systems in California, the Klamath, Eel and Russian Rivers. In each of these basins we have collected genetic data from approximately 1000 fish and for the same 18 microsatellite markers as in the earlier work, which will provide strict comparability between datasets. These studies are also evaluating the genetic composition and ancestry for trout populations upstream from barriers to anadromy. We are also just starting analysis of steelhead populations from the Central Valley and an assessment of temporal stability in genetic composition through analysis of multiple cohorts from the same population.

An exciting new component of the steelhead population structure work is the analysis of museum specimens of trout collected at the turn of the century in central California. Team members have sampled approximately 300 specimens archived at the Smithsonian Institution by biologists from Stanford University and the US Bureau of Commercial Fisheries in 1897 and 1909. These population collections include samples from the San Lorenzo, Pajaro, Guadelupe, Salinas and Eel Rivers. Preliminary analyses have confirmed the presence of recoverable genetic material in the specimens and genetic analysis is commencing.

Coho salmon

Coho salmon have been in steep decline in California over the last several decades, with many populations now extinct and only a small number of river systems that still have consistent spawning activity. All populations of coho salmon in California are now protected under the US and California Endangered Species Acts, with the southernmost California Coastal ESU currently proposed for reclassification from “threatened” to “endangered”. Information on genetic diversity can provide basic biological information to guide management, conservation and recovery of the species. We are collecting molecular genetic data on coho salmon throughout California to evaluate population structure and history. We are currently completing a study of coho salmon from 17 river systems in California from the Klamath Basin to Santa Cruz County, including almost all river systems with persistent coho salmon populations from the Klamath River to San Vicente Creek in Santa Cruz County, the southernmost extant population of the species. This phylogeographic study employs data from 18 microsatellite genes in approximately 4000 fish to evaluate population relationships, estimate gene flow and determine population history. Our analyses indicate strong support for the current ESU boundary south of the Eel River, identify several populations (Russian River and Redwood Creek, Marin Co.) of divergent ancestry and genetic origins, and indicate a pattern of isolation by distance among most remaining populations of coho salmon (Figure 1). We have also found that relative genetic distances are incrementally greater moving from comparisons between cohorts/broodyears, to comparison between tributaries and then to comparisons between river systems. Finally, the genetic data are able to identify an individual to stream of origin more than 98% of the time and down to tributary of origin more than 90% of the time. As with steelhead trout, this

extraordinarily high rate of genetic stock identification will allow the use of our data in fishery, ecological and forensic work.

Another interesting result from this work is that it has identified Redwood Creek (Marin Co.) as the source of colonists for Pine Gulch Creek in Point Reyes National Seashore. In 2001, coho salmon naturally reoccupied this stream where they had been absent for 20-30 years. We will next use these data to estimate the number of recolonizing spawners and possibly to identify the actual parents in Redwood Creek.

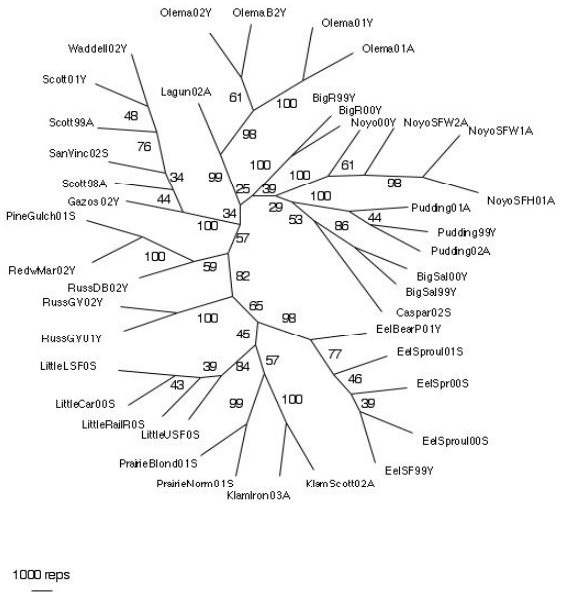

Figure 1: Relationships of coho salmon populations in California. Bootstrap consensus of 5000 neighbor-joining trees constructed with Cavalli-Sforza and Edwards Chord distances calculated from bootstrap resampled coho salmon datasets

Because of the strict three-year life cycle of coho salmon, it is necessary to evaluate genetic relationships for each of the three cohorts/broodyears in a population. To this end, we are expanding this work through evaluation of additional cohorts of many sampled populations and through collections from the few California Rivers with coho salmon populations that were not included in the study described above. In collaboration with the Salmon Population Analysis Team, we are currently analyzing approximately 2000 coho salmon tissues collected by the Santa Cruz Lab in 2003.

Chinook Salmon

Chinook salmon is the largest of the salmonids and constitutes major commercial and recreational fisheries in California. In addition, three ESUs of California chinook salmon are ESA listed. We are currently constructing a large-scale phylogeographic analysis of chinook salmon in California using 24 microsatellites and several functional DNA sequences. The larger dataset, relative to other salmonid species, is necessary to evaluate population structure in chinook salmon because of hatchery practices in the Central Valley that obscure underlying population structure. Previous work by Bodega Marine Lab has revealed several components of population structure in the Central Valley. Our work is expanding the coverage in the Central Valley to include all extant runs of chinook salmon and tripling the amount of data brought to bear on these questions of population structure. To date, we have collected genotype data from approximately 1600 adult chinook salmon in the Central Valley and have elucidated the relationship between fall- and spring- migrating populations from the same rivers. We have also extended this work to include coastal California populations of chinook salmon and found a high level of differentiation in coastal populations, which allows for easier stock identification than in the Central Valley. We are currently preparing a manuscript describing the results of the coastal chinook analyses.

Rockfishes

The Southwest Center Groundfish Research Plan ranks elucidation of population structure as a high priority. Currently, most stock assessments of rockfish assume a single randomly mating population, which is usually an unvalidated assumption. We are partnering with the Groundfish Analysis and Habitat Ecology Teams to evaluate population structure and test this assumption in rockfishes using tissue samples from Santa Cruz Laboratory trawl and long-line surveys. Santa Cruz Lab scientists have been collecting juvenile rockfish for over 20 years for estimation of recruitment. A recent increase in geographic coverage of collection cruises means that juvenile samples from some species are sufficiently spaced to allow an evaluation of population genetic structure. We have developed microsatellite markers for 4 of the rockfish species-widow, chilipepper, yellowtail and shortbelly-that are most commonly encountered and widespread in Santa Cruz Lab collection efforts. We are currently genotyping fish from the 2003 and 2004 cruises to evaluate both temporal and spatial variation in genetic composition. In addition, we are evaluating the spatial component of variation in kelp rockfish using both adult and juvenile samples collected by Center scientists. We have evaluated adult population genetic structure from Santa Cruz to San Diego and detected no differentiation whatsoever. We have also examined the "sweepstakes chance matching" hypothesis that states that recruitment will be from a numerically or geographically restricted sample of the adult population, leading to random variation in juveniles and a reduction in genetic variation. We have found no evidence to support this hypothesis in recently recruited kelp rockfish in Monterey Bay.

Genetic Baseline for Coastwide Chinook Salmon Fishery Management

The Molecular Ecology Team is collaborating with 6 other labs in Oregon, Washington, Canada and Alaska, including NOAA Northwest and Alaska Science Center Labs, to create a comprehensive genetic dataset for use in genetic stock identification and mixed stock analysis of the chinook high seas fishery. This work is funded by the Pacific Salmon Commission and is an effort to standardize the collection and reporting of microsatellite genetic data for chinook salmon. The first year of this collaborative effort resulted in the selection, optimization and standardization of 15 microsatellite markers, from a list of over 60 in use by the participating labs, for use in the construction of the coastwide baseline genetic dataset for chinook salmon. The second year is just beginning and will involve validation of the standardized markers through analysis of a "blind" sample and the construction of the baseline dataset that will include genotypes from 144 fish from each of 105 populations from Alaska to California. The Santa Cruz Laboratory is taking the lead in providing the electronic framework for data integration and reporting, although big challenges remain. We have also instigated a change in the physical standards used in data calibration and integration, which is resulting in a shift to a standard set of families, from a previously implemented locus-specific set of allele nomenclature tools. This consortium of genetic labs has been named GAPS (Genetic Analysis of Pacific Salmonids) and it is expected that a baseline genetic dataset for coho salmon will be constructed following the current effort.

Population genetic methodology and parameter estimation

Many analytical methods in population biology and fisheries require accurate estimates of population parameter values. These include population size, migration rate, mutation rate and other population characteristics. We are working on the development of novel methods for

estimating effective population size, detecting changes in effective size and estimating the loss of population genetic diversity using single samples in time. We are evaluating the accuracy and precision of these methods and assessing the robustness of the underlying assumptions using computer simulation. Many of the published methods are for populations that are at equilibrium or are not appropriate for highly structured populations, such as those of anadromous salmonids. These methods are being applied to salmonid populations to better understand population genetic history and structure and to evaluate whether they are appropriate for data from anadromous and marine fishes. We are also developing novel Bayesian methodology for the analysis of kin relationships with molecular markers that better reflect the life history of salmonids. These will be applied to the study of reproductive success in trout and to estimate heritability of variable life history traits. An additional line of work involves evaluation of the effects of kin structure on various population genetic estimation techniques using a new computer program we have developed that simulates pedigrees within populations. Preliminary analyses have shown that the effects of kin structure on genetic distances and stock identification techniques appear to be substantial.

Because so much inference in population genetic analysis depends upon an assumed mutation rate (often that it is small enough to be ignored), we are directly estimating mutation rates for microsatellite markers in steelhead trout and coho salmon. We are performing genotypic analysis of 18 microsatellite genes for ~5000 parent offspring pairs per species from Scott Ck. These are the same genes being used in studies of population structure. These estimates will greatly increase the accuracy of our population genetic analyses and provide insight into the importance of mutation and other evolutionary forces in salmonid populations.

Evaluation of Life History Variation in Steelhead Trout

We are using genetic methods to examine the genealogical relationships of alternative life history forms of steelhead trout. This work is proceeding along several lines. First, we are investigating a population of the "summer" steelhead form in the Eel River, which has a unique life history strategy and persists only in the upper reaches of the river's Middle Fork. Our analyses have revealed that the life history strategy is heritable (as opposed to facultative) and that it has been recently derived from the more common, "winter" life history strategy in the Eel River and, thus, appears to be a parallel derivation of a trait that is present only in isolated reaches of the Klamath and other rivers farther to the north. This work is in collaboration with the CDFG and Humboldt State University.

We are also studying the "resident", or rainbow trout, form in Scott Ck (Santa Cruz Co.), which are found above a 100ft high waterfall barrier. We have found that they are recently derived from the anadromous stock in the same stream. We have also determined that many fish are going over the waterfall and surviving in the stream below. Preliminary analyses indicate that they are reproductive interacting with the anadromous form below and that hybrids retain the non-migratory life history. Further analyses will reveal the full nature of these interactions.

We are also examining relative differences in genetic composition and reproductive success in hatchery and naturally spawned steelhead from Scott Ck. and analyzing how genetic composition changes from the beginning to the end of a bout of outmigration by genetically assaying individuals in a downstream migrant trap.

All of the work in Scott Creek is in close collaborative with the Salmon Ecology Team.

Coho Salmon Captive Broodstock Programs

We are working closely with two captive broodstock/reintroduction programs for coho salmon in central California, one based in Santa Cruz county and run by the Salmon Ecology Team and the Monterey Bay Salmon and Trout Project, the other on the Russian River and run by the CDFG and the Army Corp of Engineers. The goals of these programs are to rear coho salmon in captivity through the high mortality portion of their life cycle and then release/reintroduce them in appropriate streams in Santa Cruz, San Mateo, Sonoma and Marin Counties.

Molecular genetic data and analyses provide guidance to these programs in several ways. Phylogeographic analyses are used to identify populations appropriate for use in these programs and to evaluate sites for release. These analyses have led to very different guidance to the two programs, based on data indicating that the Russian River populations are isolated with no close relatives nearby, whereas Santa Cruz County populations appear to be exchanging migrants at a high rate and functioning as one large, subdivided population (Figure 1).

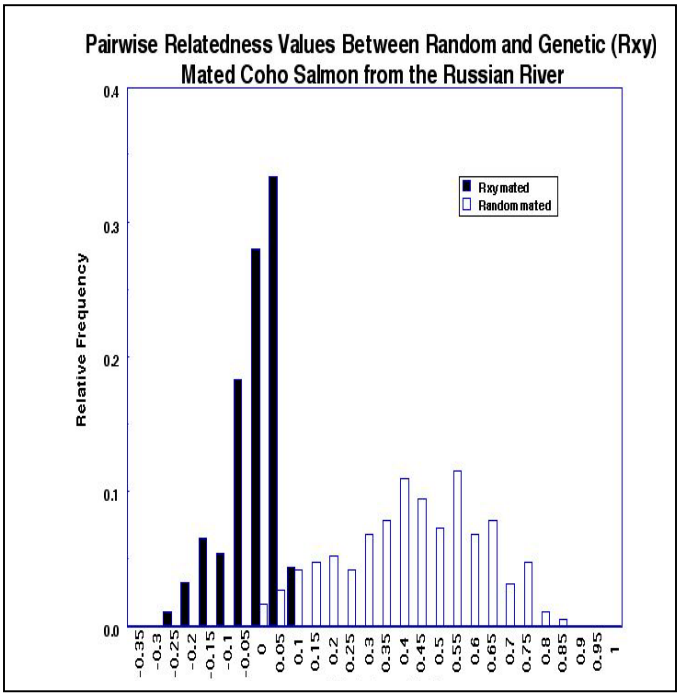

Figure 2: Frequency distribution of pairwise relatedness values for breeding pairs of coho salmon in year 1 of the Russian River captive broodstock program. Both the actual distribution of genetically paired mates and the expected distribution if mates were chosen randomly are shown.

We are also using microsatellite genotype data to help identify specific individuals for retention in the programs, through the use of methods that replicate population allele frequencies in the captive sample. This is important because typically many more individuals than are needed are raised and some criteria for retention are necessary when individuals must be released or sacrificed. Moreover, it is virtually impossible to externally determine sex in salmon before they become reproductively mature. We have thus begun to develop molecular methods to determine sex in coho salmon before they are reproductively mature, in order to ensure appropriate sex ratios in individuals held in the captive broodstock programs.

Another important application of molecular data to these captive broodstock programs is in the construction of genetically-based breeding matrices. Genetic data are used to estimate relatedness of all individuals in the captive programs, so that both inbreeding and outbreeding can be avoided, thereby maximizing effective population size and population fitness. Figure 2 shows the distribution of relatedness values in genetically mated pairs of coho salmon from Year

1 of the Russian River program and the expected distribution if they had been randomly mated. We are currently formulating an algorithm that will simultaneously incorporate information about pairwise relatedness and the expected contribution of each individual to the next generation to dynamically guide breeding efforts through the course of a bout of reproductive maturation in captive coho salmon populations. Additional conservation hatchery recommendations are also resulting from this work.

Our work has also been used to guide release/reintroduction efforts. An early success has been recorded with the discovery of coho salmon juveniles in Walker Creek (Marin Co.), where reproductively maturing adults collected from adjacent Lagunitas Creek and raised in the broodstock program were released last winter by the CDFG on the recommendation of Santa Cruz Lab staff.

Genetics

Most of the work in population genetics strives to use "neutral" genes as markers, to eliminate confounding patterns of natural selection. However, information about natural selection is crucial to understanding the process of local adaptation, which is especially prevalent in salmonids. We are thus describing structure and variation for functional genes in anadromous and marine fishes. We are also commencing investigation of the spatial patterns of variation at these genes to better understand natural selection and adaptation of fish populations and to expand our analyses of population structure to include variable gene sequences. This work is in collaboration with UC Santa Cruz and has been funded by a UC Office of the President's Postdoctoral Fellowship to support Dr. Andres Aguilar's tenure with the Molecular Ecology Team. The specific objectives of this work are to describe position and size of introns and exons, identify polymorphic sites and design assays for surveying this variation in genes believed to be important in ecological variation. Much of this work involves the use of published cDNA sequences from salmonids and other fishes to describe structure and variation of genes in species for which they have not been previously studied. As an example, we have described complete gene structure for insulin–like growth factor (IGF) and heat shock protein (HSP) genes in steelhead trout (Figure 3). We have also evaluated creatine kinase and several dehydrogenase genes in chinook salmon and a series of immune system genes in salmon, trout and rockfish. Once gene structure has been described and polymorphism identified, this information is used to

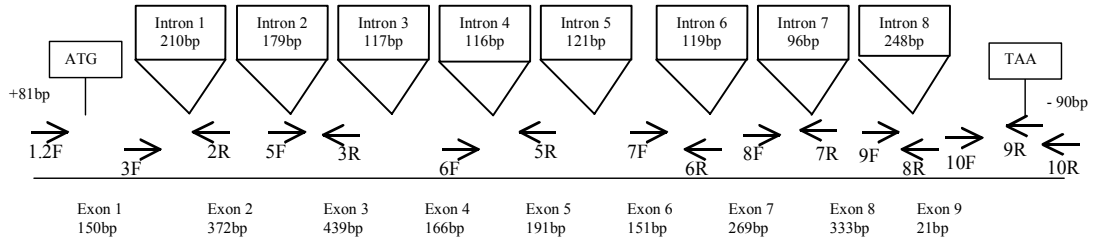

Figure 3: Heat Shock Protein (HSP) 90 Genomic Structure. The location of introns and exons in the Hsp90 gene are shown. Arrows indicate primer name, location and position used in gene elucidation. All exonic sequence shares greater than 90% sequence identity with the *O. tshawytscha* (chinook) Genbank sequence. Figure is not to scale.

develop single nucleotide polymorphism (SNP) assays. SNP assays are widely regarded as the successor to microsatellites and are expected to dominate population genetic analyses within a decade. We will use these SNP assays to evaluate patterns of natural selection in salmonid and rockfish populations.

Genetic Repository

In 2000, members of the current Molecular Ecology Team initiated a Genetic Tissue Repository for anadromous and marine fishes. This archive is a resource for genetic research on California fishes both now and in the future. Samples are taken from fish captured or handled by Santa Cruz Lab researchers and by agency and university biologists. Genetic material is made available to outside researchers with demonstrated competence in molecular genetics. All samples used in Team research are also held in the repository. The genetic archive contains both biological tissues (mainly dried fin clips) and purified, buffered DNA. Most samples entering the repository are immediately catalogued and processed, with DNA extracted using a semi-automated procedure. Purified nucleic acids are then stored frozen in a buffered solution and are much more stable over time than when they are in biological tissue. At present, the repository has material from well over 40,000 specimens, including approximate 20,0000 trout, 10,000 coho salmon, 7,500 chinook salmon and 7,000 rockfish. Future challenges include updated informatics tools for cataloguing/accession and securing continued funding for repository maintenance and growth.

Accomplishments

Publications

- Garza JC, Anderson EC. (In review). Estimation of population size with molecular markers. Molecular Ecology (invited review article).
- Anderson EC, Dunham KK. (In review). SPIP 1.0: A program for simulating pedigrees and genetic data in age-structured populations. Molecular Ecology Notes
- Lessa EP, Wlasiuk G, Garza JC. (In press) Dynamics of Genetic Differentiation in the Río Negro Tuco-tuco (Ctenomys rionegrensis) at the Local and Geographical Scales. In Mammalian Diversification: from Population Genetics to Biogeography, ed. Lacey E.
- Pastor T, Garza JC, Allen P, Amos W, Aguilar A. 2004. Low genetic variability in the highly endangered Mediterranean monk seal. Journal of Heredity 5: 291-300.
- Garza JC, Gilbert-Horvath E, Anderson J, Williams T, Spence B, Fish H. 2004. Population structure and history of steelhead trout in California. N. Pac. Anadr. Fish Comm. Tech. Rep. 5: 129-131
- Garza JC, Gilbert-Horvath E. 2004. Report on the genetics of coho salmon (Oncorhynchus kisutch) held at Warm Springs (Don Clausen) Hatchery for recovery efforts in the Russian River. 17pgs.
- Clemento AC. 2004. Discerning subpopulation structure of Oncorhynchus mykiss in the Eel River. Masters Thesis, Humboldt State University (work done at Santa Cruz Lab).
- Anderson EC, Slatkin M. 2004. Population genetic basis of haplotype blocks in the 5q31 region. American Journal of Human Genetics 74:40-49.
- Anderson EC, Novembre J. 2003. Finding haplotype block boundaries by using the minimum description length criterion. American Journal of Human Genetics 73:336–354.

- Bjorkstedt EB, Spence B, Garza JC, Hankin D, Fuller D, Jones W, Smith J, Macedo R. 2004. Population structure of Evolutionarily Significant Units of chinook salmon, coho salmon and steelhead in the North-Central California Coast Recovery Domain, Draft document. 121 pgs.
- Hayes SA, Garza JC, Bond M, Hanson C, MacFarlane RB. 2003. Monterey Bay Salmon and Trout Project Production Management Recommendations, 41 pgs.
- Wlasiuk G, Garza JC, Lessa EP. 2003. Genetic and geographic differentiation in the Río Negro tuco-tuco (Ctenomys rionegrensis): inferring the roles of migration and drift from multiple genetic markers. Evolution 57: 913-926.

Presentations

- Scripps Institute of Oceanography, Marine Biology Seminar-2004 (Invited: Garza)
- Society for the Study of Evolution and the American Society of Naturalists Annual Meeting-2004 (Pearse, Gilbert, Anderson, Aguilar; 4 presentations)
- Biannual Coastwide Salmon Genetics Meeting, Newport OR-2004 (Blankenship, Clemento, Pearse; 3 presentations)
- Conservation of Rockfishes: Ecological Genetics and Stock Structure Symposium, NWFSC-2004 (poster: Aguilar & Garza)
- Recovery Science Review Panel, Santa Cruz Lab-2004 (Garza)
- Monterey Bay Aquarium Sea Otter Research Symposium-2004 (Invited: Garza)
- Salmonid Restoration Federation Annual Meeting-2004 (Invited: Garza)
- Board of Directors of the Monterey Bay Salmon Trout Project-2004 (Invited: Garza)
- Santa Clara University Natural Sciences Seminar-2003 (Invited: Garza)
- Bay Area Conservation Biology Annual Symposium-2003 (Garza)
- North Pacific Anadromous Fish Commission Stock ID Workshop-2003 (Garza)
- Population Genetics in Animal Conservation Workshop-2003 (Garza, Anderson)
- American Fisheries Society Annual Meeting-2003 (Garza)
- Santa Cruz County Blue Circle Forum-2003 (Garza)
- California Population and Evolutionary Geneticists Annual Meeting, UC Irvine-2003 (Clemento, Aguilar, Blankenship)
- UC Berkeley, Environmental Sciences Seminar-2003 (Invited: Garza)
- Monterey Bay Aquarium Research Institute-2003 (Invited: Garza)
- Bodega Marine Lab Seminar-2003 (Invited: Garza)
- Society for the Study of Evolution and the American Society of Naturalists Annual Meeting-2003 (Garza, Gilbert; 2 presentations)
- University of Nevada, Reno Biology Seminar-2002 (Invited: Garza)
- UC Berkeley, Integrative Biology Seminar-2002 (Invited: Garza)
- Biannual Coastwide Salmon Genetics Meeting, Bodega CA-2002 (Garza; 2 presentations)
- American Fisheries Society Annual Meeting, Cal/Neva Section-2002
- Salmonid Restoration Federation Annual Meeting-2002 (Invited: Garza)
- FishNet 4C Symposium on Cooperative Efforts for Salmonid Conservation-2002 (Invited: Garza)
- Society for the Advancement of Chicanos and Native Americans in Science Annual Meeting-2002 (Invited: Garza)

- California Population and Evolutionary Geneticists Annual Meeting, UC Santa Barbara-2002 (Garza).

Committees and Service

- Editorial Review Board, Molecular Ecology (Garza)
- Federal Technical Recovery Team for ESA listed Salmonids in the North Central California Coast Planning Domain: 2002-2004 (Garza)
- Federal Technical Recovery Team for ESA listed Salmonids in the Southern California Planning Domain: 2002-2004 (Anderson)
- Russian River Coho Salmon Recovery Planning Workgroup: 2002-2004 (Garza)
- Joint Federal/State Coastal Monitoring Plan Development Workgroup: 2004 (Garza; Anderson)
- NOAA Fisheries Southwest Equal Employment Opportunity Advisory Committee-2002-04 (Garza)
- Biological Review Team for West Coast salmonids: 2003 (Garza)
- Thesis Committee, Anthony Clemento: M.S. in Fisheries, Humboldt State University: 2004 (Garza)
- Dissertation Committee, Yean Wang: Ph.D. in Biology, University of Sydney: 2004 (Garza)
- Senior Honors Thesis Advisor, Cherish Ryals: B.S. in Biology, UC Santa Cruz: 2004 (Garza)
- Thesis Committee, Kristy Deiner: M.S. in Biology, Sonoma State University: 2003 (Garza)

Extramural Research Support

- Pacific States Marine Fisheries Commission: Genetic Ancestry and Origins of Southern California Trout-$9,954: 2004-2005
- Pacific Salmon Commission-Chinook Technical Committee: Coastwide DNA database for Mixed Stock Analysis of Chinook Salmon-$137,281: 2003-2005
- UC Office of the President Postdoctoral Fellowship-Thermal Adaptation in Steelhead Trout, ~$75,000 (Aguilar Fellowship, but Garza PI): 2003-2005.
- US Fish and Wildlife Service: Comprehensive Assessment of Genetic Population Structure and Diversity for Central Valley Chinook Salmon-$385,869: 2002-2005
- USGS-Biological Resources Division: Population Genetics of the Sea Otter in California-$84,876: 2003-2004
- Pacific States Marine Fisheries Commission: Genetic Resource Monitoring in Russian River Coho Salmon-$73,753: 2003-2004

Future Research Directions

Future work in the Molecular Ecology Team will continue to emphasize collaboration with NOAA researchers, primarily Santa Cruz Laboratory teams, and biologists from other agencies and universities. Our future research objectives are:

- Work with the Salmon Population Analysis and Salmon Teams and to provide a comprehensive picture of genetic population structure in the Southern Oregon/Northern California coho salmon ESU and to finish elucidating population structure of steelhead trout in southern California ESU and the Klamath River system. The Klamath River work will be coupled with analyses of otolith microchemistry to examine the relationship between genealogical structure and migratory behavior. The southern California ESU work will determine ancestry of trout behind recent man-made barriers and is a collaborative effort involving Sonoma State University.

- Use newly available gene maps to identify genes involved in traits such as age at maturity, growth rate, disease resistance and various aspects of migratory behavior in both steelhead trout and chinook salmon. We will first confirm linkage relationships, for California steelhead trout and chinook salmon populations, from maps being constructed in other laboratories for other salmonid populations. We will then supplement these maps as necessary and use them in linkage and linkage disequilibrium mapping efforts.

- Develop genomics tools such as expression microarrays to identify specific genes involved in these traits and to describe the biochemical basis of ecological, behavioral and physiological variation. We also hope to use this gene expression data to develop assays for physiological processes that can be used by collaborating labs. Of great interest will be the investigation of whether similar life history variants (i.e. temporal runs) use similar biochemical mechanisms to solve similar ecological problems. To advance these goals, we are developing a collaborative effort with CDFG, Humboldt State University and UC Santa Cruz to initiate a research-breeding program for chinook salmon, and possibly steelhead trout, at the Feather River Hatchery in the Central Valley. We will use this program to estimate heritability and study inheritance of age at maturation, migration and hatchery domestication-related behaviors.

- Develop new methods in genetic trophic ecology to estimate consumption of protected and fishery important species by pinnipeds and to identify habitat components important for juvenile salmon growth. This will involve genetic analysis of feces and stomach contents from pinnipeds and juvenile salmonids. We hope to provide stock-specific estimates of pinniped predation and correlate salmonid dietary components with bioaccumulation pathways for environmental contaminants.

- Expand efforts in statistical genetic methodology, through development of new likelihood and Bayesian methods, and evaluate new uses of genetic data through simulation and analytical derivation. Topics to be investigated include the refinement of traditional population genetic methods to better reflect salmonid life history, the development of optimization models to minimize selection in hatcheries, an analytical evaluation of the use of SNP data to replace coded wired tags in hatcheries in the face of mark selective fisheries, and the use of Bayesian prior probabilities in phylogeographic analyses.

Groundfish Habitat Ecology Team

Introduction

The reauthorized Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) has created a mandate for NOAA Fisheries to identify and describe essential fish habitat (EFH) for managed species, and to protect and restore (where necessary) these habitats. A second mandate of the Act, which has direct relevance to EFH, is to identify and rebuild those managed stocks that are overfished. Several groundfish species on the west coast have been designated as overfished; it is especially important to characterize and protect EFH of these species and to improve our assessments of these stocks. From past research we know that adults of many species of rockfishes, in particular, are difficult (or impossible) to accurately appraise with traditional survey methodologies such as surface-based fishing and acoustic gear. This is due to the close association between many of these species and their rugged, rocky heterogeneous habitats. Consequently, alternative techniques are necessary to improve assessments and track the recovery for some of these species.

The Santa Cruz Laboratory has developed a research program to effectively respond to the MSFCMA mandates with respect to West Coast groundfishes. Our Habitat Ecology team currently includes five research biologists. Several funding opportunities for marine groundfish habitat research both within Fisheries and from other NOAA offices (Sea Grant, NURP, Ocean Exploration, NOS), USGS, state agencies, and private foundations have been successfully pursued in recent years. We plan to augment support for our program from these and other funding sources in the future.

Objectives

- Characterize associations of deep-water habitats and groundfishes
- Improve groundfish assessments over untrawlable habitats
- Develop new technology to map seafloor habitats
- Evaluate rockfish recruitment, growth, and associated ocean conditions
- Consider marine protected areas to conserve, rebuild, and manage groundfish and habitats
- Inform ocean policy, resource management, and public knowledge on marine fishery issues

Research and Management Support Activities

Cowcod Conservation Areas Surveys:

In collaboration with researchers from the University of California Santa Barbara, Moss Landing Marine Labs, and CA Dept. Fish and Game and with funding from NMFS Offices of Protected Resources and Habitat Conservation, NOAA NURP, NOAA Center For MPA Science, and the David and Lucile Packard Foundation, we have initiated a monitoring protocol for fish, macro invertebrates, habitats, and incidence of fishing gear and disturbance on offshore banks in and around the Cowcod Conservation Areas (CCA) off southern CA. Underwater surveys of groundfish populations and their habitats were conducted off southern California using non-extractive video-transect methodologies and direct observations from an occupied research submersible (*Delta*). We asked two fundamental questions of our research: (1) Are the CCAs

meeting their objective to protect and rebuild the cowcod population and (2) Can we effectively survey cowcod (and, by extension, other benthic fishes) by direct observation rather than by conventional techniques, such as hook and line or bottom trawl. These surveys were conducted over the ten major offshore rocky banks inside the newly established CCAs. All of these banks are longtime fishing sites.

Digital, georeferenced maps of the seafloor, acquired from available side-scan sonar, multibeam bathymetry, seismic reflection and other past geophysical surveys, were used to identify and select sites of appropriate bottom type and depth. Past and recent groundfish catch and effort records also were used to assist in locating appropriate survey sites. We tracked the submersible in real-time in relationship to depth and seafloor habitats. Our sampling design included those habitats classified as mixed or hard rock substrata within a depth range from 30-300 m (except cowcod, 75-300 m). These habitats were gridded into 2.25 km^2 cells, and the cells were randomly selected to locate dive sites. We made a total of 130 submersible dives, surveying a wide range of micro-scale habitats, from sheer, high relief seamounts to flat mud seafloor. During the 30-day survey, we counted a total of 121,119 fishes representing 119 taxa; dwarf rockfish species and young-of-the-year were most abundant. We observed at least 250 cowcods, ranging from newly settled young-of-the-year (about 6 cm) to a few survivors (over 100 cm). We used line transect methodology to estimate densities (and associated CV's) of cowcods on the rocky banks within the CCAs (Figure 1). Absolute abundance of cowcods (juvenile and adults separately) was estimated by expanding the density estimates by the total area represented by the habitats surveyed on each bank.

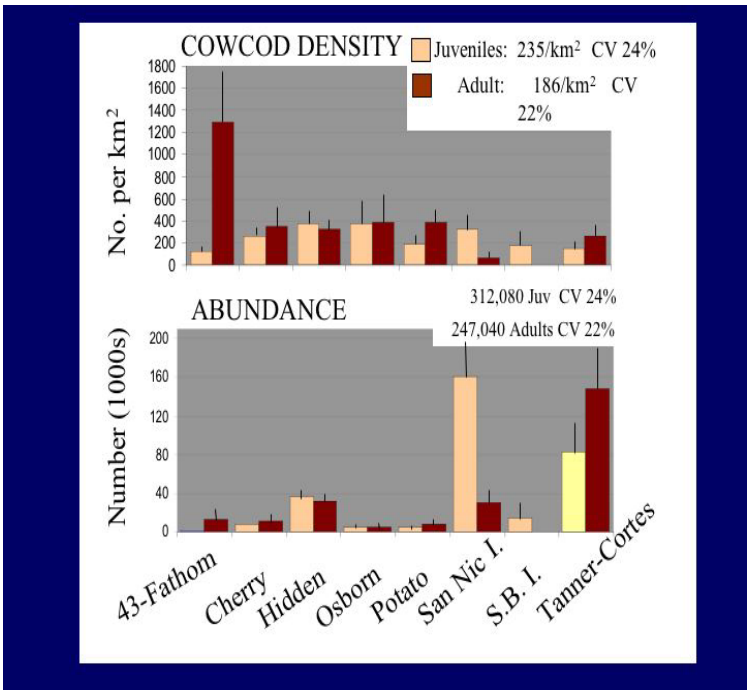

Figure 1 Density and absolute abundance of cowcod on rocky banks inside the Cowcod Conservation Areas.

Arguably the most important immediate finding is that we have successfully demonstrated the feasibility of conducting a fishery-independent assessment of cowcod using visual, non-extractive, habitat-specific survey methodologies. We have calculated a bimodal size distribution for the cowcod population, comprising a significant number of young members of the successful 1999-year class. The significance of this finding is that this year class represents the nascent recovery of this population and allows us to structure our future monitoring strategy for the CCAs. We have characterized the depth distribution of cowcod within the CCAs. We have recently provided this information to the Pacific Fisheries Management Council (PFMC) to

inform a proposal by the fishing community to modifying the boundaries of the CCAs. Hopefully our information will support a decision to maintain the present boundaries for 2005-06 rather than reduce the amount of protected area.

Structure-forming invertebrates as components of benthic habitat:

There is increasing interest by science and conservation communities in the potential impacts that fishing activities have on megafaunal benthic invertebrates occurring in continental shelf and slope ecosystems. Megafaunal invertebrates (> 5cm) are significant components of biodiversity, play important functional ecological roles, and can be indicators of long-term environmental conditions. Because large invertebrates such as sponges and corals enhance the diversity and structural component of fish habitat and are vulnerable to impacts by at least some fisheries, they also may signify habitat areas of particular concern (HAPC) and as such would be protected under the MSFCMA. Deep-sea corals (DSC), such as gorgonians (sea fans), antipaththarians (black corals), scleractinians (stony corals), and hydrocorals, are of particular interest because they are often long-lived and slow-growing, poorly studied, and in certain situations vulnerable to human activities. Other megafaunal invertebrates, such as crinoids, basketstars, and sponges, may also enhance the structural components of fish habitat and may be disturbed or destroyed by some fishing activities.

We are collaborating with B. Tissot (Washington State University, Invertebrate Ecologist) to describe patterns in the density, distribution, and size of structure-forming megafaunal invertebrates on the deep rocky banks and outcrops in the CCAs. Our specific objectives are to identify structure-forming invertebrates, quantify their density and size distributions specific to depth and substratum types, and quantify associations between large, structure-forming invertebrates and other organisms, particularly fishes. About 520,000 megafaunal invertebrates of 15 taxa were observed. Echinoderms, such as brittlestars, urchins, and crinoids, were most abundant. Deep sea corals and sponges were the largest structure-forming invertebrates but were relatively uncommon. The corals are patchy in distribution, and found in low-relief mixed cobble-boulder-sand habitats at 100-225 m depths. Until our surveys, black corals (genus *Antipathes)* off southern California were completely unknown to science. D. Opresko, (Oak Ridge National Laboratory) has described and named at least one new species based on the specimens and video images that we collected. Few large invertebrates and almost no fishes appear to be associated with these animals. Only 1.8% of the 8,883 larger invertebrates had other organisms lying on or attached to them, and the vast majority of these organisms were other invertebrates, including crinoids, sponges, crabs, basketstars, brittlestars, seastars, anemones and salps. This suggests that fishes are not intimately associated with structure-forming invertebrates in the areas of our daytime surveys. Analysis of spatial associations between fishes and large structure-forming invertebrates indicated that six of 108 species were found more often adjacent to colonies than predicted by their abundance, suggesting that there may be spatial associations that don't involve physically touching the corals. However, the median distances between these species and large invertebrates were 1.0-5.5m, and thus not particularly close. It is likely that these fishes and structure-forming invertebrates co-occur in the same types of habitats and that there is no functional relationship between these two groups of organisms. This comprehensive survey and analysis of the distribution, abundance, and species composition of large invertebrates in the Southern California Bight are unique and contribute

new and significant information to our understanding of biodiversity, indicators of environmental conditions, and components of essential fish habitats.

Intercalibration of direct observation and extractive survey methods:

In August-September 2004, we are using direct observation methods from an occupied submersible to survey fishes and habitats in 100 m water depth at the location of longline surveys conducted off central California by the Groundfish Analysis Team monthly for the past two years. Our objective is to compare occupied submersible quantitative transect methods with bottom longline methods for determining abundance, size and species composition, catchability coefficients and selectivity, and appropriate conversion factors for relative and absolute abundance. Quantitative transect methods, collection of accurate visual observation and navigation data, database management and analysis follow protocols based on our past experience with in situ methods. This study includes participation by a commercial longline fisherman in the submersible operations. Our results should contribute to improved assessments of groundfish stocks in untrawlable habitat off California.

Fish and habitats at varying spatial scales:

A team member (post-doctoral fellow: T.Anderson) is addressing the relationship between patterns in groundfish distribution and abundance and seafloor habitats at a range of spatial scales. This post-doctoral fellowship position is funded jointly by NMFS-SCL and USGS-Coastal and Marine Geology, and has been particularly effective in establishing a stronger research connection between the two laboratories.

Many species of groundfishes are strongly associated with specific substratum types. A predictable relationship between organism and habitat presents the possibility of using habitat as a proxy for distribution and abundance of fish species over large areas. The ability to extrapolate up to large scales relies on the capability to map the seafloor, over areas of interest, and calculate the availability of benthic habitats. Acoustic systems such as sidescan and multibeam sonars have been developed that collect wide swaths of seafloor data and thus can map large regions quickly. The interpretation of acoustic data into seafloor classifications however is complex, and requires reliable and accurate groundtruthing to transform the acoustic signal into biologically meaningful information. In a collaborative effort between USGS, NOAA Fisheries, and the National Marine Sanctuaries off California (Cordell Bank, Channel Islands, and Monterey Bay) we are testing a novel application of a camera sled to groundtruth seafloor habitat maps in real time. To characterize abiotic and biotic aspects of the seafloor, we conduct a series of multidirectional transects using a mini camera sled. Video observations are annotated in real time every 30 seconds using an electronic programmable keypad integrated with navigational software. These seafloor characterizations adequately describe substratum types, bedform, relief, and presence of benthic macro-organisms. These data were used to groundtruth acoustic mosaics of the seafloor within hours of its collection, providing an initial description of seafloor habitats and some aspects of their communities. This approach is ideal for those projects that require rapid feedback.

Develop New Technologies

One of our challenges is to efficiently relate small-scale observations and assessments of animal-habitat associations to the large geographic scales on which benthic fisheries operate.

Laser line scan (LLS) systems potentially can serve as a bridge between fine resolution, low coverage video survey tools (*e.g.*, remotely-operated vehicle (ROV), occupied submersible, towed sled) and coarse resolution, high coverage acoustic technologies (*e.g.*, multibeam and sidescan sonar). In an evaluation of LLS for fishery habitat assessments, a survey was conducted by the Habitat Ecology Team in FY02 off the central coast of California using a Northrop-Grumman SM-2000 LLS. A video survey also was conducted using an ROV across parts of the study area to groundtruth the LLS data and to compare observations made from a forward-looking video camera with those from LLS reflectance imagery. The LLS was successful in generating high resolution (1-2 cm across-track) imagery of rock outcrops, sand waves and ripples, drift kelp, patches of large anemones, groups of fishes off and on the seafloor, starfish, sea pens, and salp chains. As expected, the LLS system provided imagery of higher aerial coverage but with a lower degree of taxonomic identification than the ROV video.

Developing the capability to process and mosaic imagery and produce seafloor maps is a significant step in advancing the efficient application of LLS technology. To assess the mapping capabilities of the system, we have generated a tiled-image mosaic of georeferenced LLS data with 2-cm pixel resolution across the survey area. The data acquisition hardware down sampled or did not log all sensor data, which made an accurate expression of the LLS configuration (i.e. instrument settings) difficult to achieve. As a result, a large degree of detail and object recognition observed in the original LLS imagery was lost upon geometric translation. However, combined with information obtained from reviewing the original imagery, the mosaic representation did demonstrate spatial configuration and context of organisms and geologic features at varying spatial scales. The mosaicing process exposed limitations with data acquisition and georeferencing that must to be addressed before this technology can advance as a habitat assessment tool. Future improvements to the LLS system and data processing will contribute to our understanding of fish-habitat relationships and coastal physical processes that influence dynamic benthic habitats.

Evaluate rockfish recruitment, growth, and associated ocean conditions

Subtidal With the decrease in population size of the many of the rockfish stocks, accurate forecasting of the biomass that will recruit to the fishery is needed to adequately manage the stocks and set catch quotas. Since 1983, biologists from the Santa Cruz Laboratory have conducted nearshore juvenile rockfish recruitment surveys off the coast of northern California to evaluate long-term trends in annual abundance and possible mechanisms for the variation. Also, since the lab has moved to Santa Cruz, a new sampling site has been established at the southern end of Monterey Bay for comparisons of recruitment and other life history aspects with that information collected to the north.

In Northern California we have estimated annual juvenile rockfish abundance in the nearshore environment during 21 years, and evaluated the relationships of abundance to oceanographic variables to understand the variation in year-class strength. We estimated the abundance of juvenile blue (*Sebastes mystinus*), yellowtail (*S. flavidus*), and black (*S. melanops*) rockfishes. Data on juvenile rockfish abundance were collected using subtidal survey scuba methodologies. Juvenile rockfish abundance was highly variable from year-to-year, ranging from 181 fish/min to 0.01 fish/min.

Annual trends in abundance were similar for the three species during the 21 years of study (HabEcol Figure 2). We compared the juvenile rockfish abundances to sea level anomaly, near shore temperature, and offshore Ekman transport. Sea level anomaly and temperature had the greatest influence in explaining interannual variation. Seasonality of the oceanographic variables was investigated and events occurring early in the year (February and March) had the greatest correlations with rockfish abundance. We surmise that year class strength is determined in the larval phase when temperature and patterns in water movement can affect the larvae greatly.

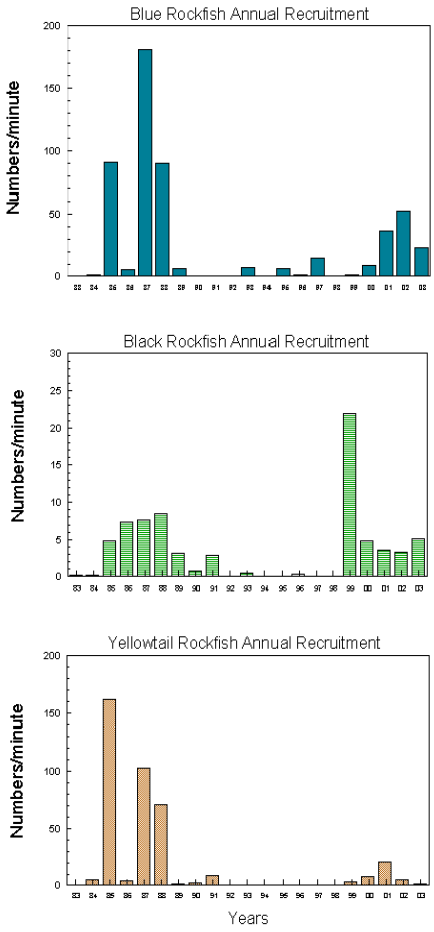

Figure 2. Annual juvenile rockfish abundance index for blue, black, and yellowtail rockfish (mean number of rockfish counted per minute) by year.

Our staff is coordinating with similar subtidal survey efforts coastwide, in an effort to standardize assessment methods and interpret results among all surveys. We have helped train divers in standard fish and invertebrate survey methodologies, and taught a segment of a course on juvenile rockfish identification. Data collected through this method will be analyzed to determine coastwide trends among nearshore fishes.

Long-term Indices of Annual Growth in Long-lived Groundfishes

To better determine the impacts of ocean variability on fishery productivity, we are developing multi-decadal chronologies of rockfish otolith growth and relating those chronologies to long-term records of the ocean physical environment. We build upon our previous study in which time series were established for *Sebastes pinniger* and *S. diploproa* for the periods 1920 to 1988 and 1896 and 1988, respectively. Otoliths from fish caught in 1989-95 are now being used to extend these chronologies through 1995 and increase sample numbers along the chronology. In addition, we have investigated alternative measuring techniques and adapted age-validation techniques from dendrochronology (tree-ring analysis). On a subsample of 43 *S. diploproa* otoliths collected in 1989 and ranging from 30-84 years in age, we measured all growth increments along a continuous axis from the dorsal proximal edge to the focus. After removing age-related growth patterns and homogenizing variance, average correlation among otoliths is 0.56 and all correlations were significant ($\alpha = 0.05$). Agreement among otolith growth patterns demonstrates a synchronous, climate-induced growth signal that can be used for age validation. If a sample does not correlate with the others, there is likely an error and the otolith should be

reanalyzed. This approach, referred to as crossdating, can serve as a new means by which to ensure all growth increments have been assigned the correct calendar year and that all fish have been correctly aged. Accuracy in all otolith time series is crucial for building high-resolution chronologies that reflect climatic variability. The average of all *S. diploproa* otolith time series was significantly correlated with upwelling index ($r = 0.43$ $p = 0.002$), the Pacific Decadal Oscillation ($r = -0.26$ $p = 0.027$), and the El Niño Northern Oscillation Index ($r = 0.45$ $p = 0.002$), thereby corroborating accuracy.

Future research will be necessary to evaluate other fish species for successful crossdating. Most likely, crossdating will be appropriate for other long-lived rockfish species and additional marine and freshwater fishes, given the clarity of their otolith cross sections. The spatial extent over which otolith are collected must also be explored. This present study includes rockfish from a geographic area spanning five degrees latitude. Yet spatial variability across larger areas may induce site-specific otolith growth patterns, which would reduce interseries correlations and the power of crossdating. Once the appropriate spatial scale for successful crossdating is established, master chronologies could be developed for each species location and made available on the Internet. Individual otoliths could then be crossdated against the existing master chronology such that a large number of otoliths would not be necessary to generate a master chronology every time crossdating is applied. This would greatly expedite crossdating and would allow for age validation from small samples of otoliths.

Marine Protected Areas

For the past 8 years, our staff has initiated and led efforts to evaluate marine protected areas (MPAs) as a supplemental tool for groundfish management on the West Coast. Early on, we organized and convened the first workshop on marine harvest refugia to conserve and manage rockfishes and continued these discussions in a special symposium on marine protected areas for California. Team members have served as scientific advisers on MPA issues to the Pacific Fisheries Management Council, on the Master Plan Team for California's Marine Life Protection Act, to the Alliance of Communities for Sustainable Fisheries (representatives of the fishing community on the central coast), as a member of NCEAS (National Center for Ecological Analysis and Synthesis) working group "Development of Tools for the Practical Design of Marine Reserves", and on the MPA Working Group of Monterey Bay National Marine Sanctuary. We have contributed to development of a NOAA Fisheries strategy for MPAs, which included an evaluation of the existing NMFS MPAs (or area based management measures).

MPAs are now a cross cutting issue within NOAA Fisheries and are being evaluated and implemented for a host of purposes ranging from stock rebuilding plans to endangered species protection. Differing scientific views and interpretations can create confusion and concern over the role of MPAs in the management of the nation's fisheries and the conservation of its marine biodiversity. To address this problem, Santa Cruz Lab (L. Wooninck; Church Grimes) and NOAA's National Marine Protected Areas Center-Science Institute are convening a technical working group to develop the scientific information necessary to integrate MPAs with the broader context of fisheries. The working group will participate in a series of focused workshops over a span of two years to discuss and define concepts and issues and to develop a rational approach for integration of MPAs and traditional fishery science and management. The working group will be composed of scientists, fishery managers and representatives from the fishing

industry and conservation community with appropriate expertise in marine ecology and fishery science and management.

We are coordinating our efforts with those of the National Fisheries Conservation Center and the PFMC's Science and Statistical Committee marine reserve subcommittee, and encourage synergism based on a shared focus. We are working closely with PFMC's staff to ensure that the information generated by the working group has effective and timely applications for PFMC's management schedule. We have presented a status report of our integration project to the PFMC, and their SSC and Habitat and Conservation advisory panel. The SSC provided positive and favorable comment to the PFMC that endorsed our integration project.

Accomplishments

Publications

- Black, B.A., G. W. Boehlert, and M. M. Yoklavich. In Review. Using tree-ring crossdating techniques to validate age in longlived fishes. Canadian Journal of Fisheries and Aquatic Sciences.
- Allen, L., M. Yoklavich, and G. Cailliet. In Press. Bay and estuarine fishes. In: L. Allen, M. Horn, and D. Pondella (eds.), Ecology of California marine fishes. University of California Press.
- Anderson, T., M. Yoklavich, and S. Eittreim. In Press. Linking fine-scale groundfish distributions with large-scale seafloor maps: issues and challenges of combining biological and geological data. In: In P. Barnes and J. Thomas (eds). Benthic habitats and the effects of fishing. AFS Symposium 41, Bethesda, Maryland.
- Love, M. and M. Yoklavich. In Press. Fishes on deep rock habitats. In: L. Allen, M. Horn, and D. Pondella (eds.), Ecology of California marine fishes. University of California Press.
- Mills, K., S. Ralston, T. Laidig, and W. Sydeman. In Press. Functional response curves and the use of top predator diet as indicators of pelagic juvenile rockfish (Sebastes spp.) abundance in the California Current system. Fisheries Oceanography.
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- Starr, R., M. Carr, J. Caselle, J. Estes, C. Pomeroy, C. Syms, D. VenTresca, and M. Yoklavich. 2004. A review of the ecological effectiveness of subtidal marine reserves in Central California. Part I: Synopsis of scientific investigations. Marine Sanctuaries Conservation Series MSD-04-2. NOAA Marine Sanctuaries Division, Silver Spring, MD. 128 p.
- Starr, R., M. Carr, J. Caselle, J. Estes, C. Syms, D. VenTresca, and M. Yoklavich. 2004. A review of the ecological effectiveness of subtidal marine reserves in Central California. Part II: Summary of existing marine reserves in Central California and their potential benefits. Marine Sanctuaries Conservation Series MSD-04-3. NOAA Marine Sanctuaries Division, Silver Spring, MD. 13 p.

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- Boehlert, G., B. Black, and M. Yoklavich. 2003. Developing Time Series of Growth Increments in Otoliths of Long-lived Fishes: Validating Ages and Showing the Relationship to Ocean Variability. Eos Trans. AGU, 84(52), Ocean Sci. Meet. Suppl., Abstract OS42B-12.
- Brock, R., J. Bohnsack, M. Fogarty, S. Murawski, M. Yoklavich, and M. Love. 2003. Marine fisheries of the USA: moving from single-species management to a more holistic ecosystem-based approach. In: J. Beumer, A. Grant, and D. Smith (eds.), Aquatic protected areas: what works best and how do we know?, p. 521-531. University of Queensland Printery, St. Lucia, Queensland, Australia.
- Laidig, T., D. Pearson, and L. Sinclair. 2003. Age and growth of blue rockfish (Sebastes mystinus) from central and northern California. Fishery Bulletin 101(4):800-808.
- Yoklavich, M., C. Grimes, and W. Wakefield. 2003. Using laser line scan imaging technology to assess deepwater seafloor habitats in the Monterey Bay National Marine Sanctuary. Marine Technology Society Journal 37(1):18-26.
- Love, M., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. University of California Press, Berkeley, California. 405 p.
- Yoklavich, M., G. Cailliet, D. Oxman, J. Barry, and D. Lindquist. 2002. Fishes. In: J. Caffrey, et al. (eds.), Changes in a California estuary: a profile of Elkhorn Slough, chapter 10 (p. 163-185). Elkhorn Slough Foundation, Moss Landing, California.
- Yoklavich, M., G. Cailliet, R. Lea, H. G. Greene, R. Starr, J. de Marignac, and J. Field. 2002. Deepwater habitat and fish resources associated with the Big Creek Ecological Reserve. CalCOFI Reports 43:120-140.

Presentations

- 13th Western Groundfish Conference. Victoria, BC, 2004 (Amend, Anderson, Laidig,Yoklavich; 7 presentations)
- UO Institute Marine Biology Seminar Series, Charleston, 2004 (Invited: Yoklavich)
- Friends of Moss Landing Marine Labs Lecture Series, CA, 2004 (Invited: Yoklavich)
- International Otolith Symposium, Townville, AU, 2004 (Black, Boehlert, Yoklavich)
- AGU Ocean Sciences, Portland, OR, 2004 (Boehlert, Black, Yoklavich)
- NMFS Underwater Video Analysis Workshop, Seattle, WA, 2004 (Yoklavich)
- PFMC, Foster City, CA, 2004 (Wooninck)
- 133rd Annual Meeting of American Fisheries Society, Quebec City, Canada, 2003 (Invited: Wooninck; Yoklavich; 2 presentations)
- Oceans 2003, San Diego, CA (Invited: Yoklavich)
- Census of Marine Life Workshop:Canyons and Seamounts, Newport, OR, 2003 (Invited: Yoklavich)
- GeoHab: Marine Geological Habitat Mapping Conference, Moss Landing, CA, 2002 (Yoklavich)
- Moss Landing Marine Laboratories, Deepsea Ecology Seminar, 2002 (Yoklavich)
- CA Artificial Reef Enhancement Workshop, Huntington Beach, 2002 (Yoklavich)
- American Institute of Fishery Research Biologists, San Jose, CA 2002 (Yoklavich)

Committees and Service

- PFMC Technical Rev. Committee: West Coast Groundfish EFH EIS (Yoklavich)
- Coordinated and co-authored "The Pacific Region's Marine Habitats" chapter of Our Living Oceans Habitats (Yoklavich)
- Monterey Bay National Marine Sanctuary MPA Working Group (Wooninck); Research Activities Panel (Yoklavich)
- Moss Landing Marine Laboratories Graduate Student Committee (Yoklavich)
- NCEAS Working Group On Marine Reserve Design (Yoklavich)
- California Marine Life Protection Act Master Plan Team Member (Yoklavich)
- MPA Inventory Interagency working group (Wooninck)
- Natl Fisheries Conservation Cntr MPA Conference, Long Beach, CA (Wooninck)
- NOAA Planning team for the science integration of MPAs and traditional fishery science and management (Wooninck, co-PI; Yoklavich, working group member)
- Santa Cruz Laboratory outreach team (Wooninck, lead)
- NOAA Multibeam Sonar Workshops 2003-04 (Amend, Yoklavich)
- CDFG and PSMFC Marine Metadata Workshop (Amend)
- CDFG and PSMFC NE Pacific Marine Habitat Classification Workshop (Amend)
- NMFS Underwater Video Analysis Workshop, Seattle, WA (Laidig, Yoklavich)
- Alliance for Coastal Technologies Acoustic Remote Sensing Workshop (Amend, Yoklavich)
- CDFG Committee on Cooperative Research for Assessment of Nearshore Ecosystems (Laidig)
- NOAA Unit Dive Supervisor for Monterey Bay Region (Laidig)

Extramural Research Support

- Analytical Framework and Risk Assessment Tools for Pacific Coast Groundfish EFH. (2004) Yoklavich, Copps, et al. Sponsor: NOAA Fisheries ($75K)
- Cowcod Conservation Areas Surveys. (2002) Yoklavich and Love. Sponsor: NOAA NURP ($210K); Packard Foundation ($250K); NMFS F/PR ($70K); F/HC ($70K); NOAA MPA Science Center ($28K)
- Long-term indices of annual growth in long-lived groundfishes. Yoklavich and Boehlert. (2002-03) Sponsor: NMFS FATE ($160K)
- Using lasers to explore seafloor habitats. Yoklavich and Grimes. (2001-02) Sponsor:NOAA Ocean Exploration ($100K); NURP ($200K)

Future Research Directions

- Use already-established baseline information from 2002 surveys to monitor Cowcod Conservation Areas off Southern California by conducting direct observation surveys to assess spatial and temporal trends in abundance, size structure, and diversity of groundfish populations and associated habitats. Collaborators (UCSB, CDFG, Oregon State University)
- Identify and rescue existing data on Deep Sea Corals (and other structure-forming macroinvertebrates) off California, develop georeferenced database on distribution and abundance of DSCs and associated fishes and habitats, improve our ability to assess and

protect DSC stocks, and evaluate DSC as EFH for groundfish. Collaborators (UCSB, MBARI, Washington State University)

- Development and maintenance of comprehensive, accessible databases of all geo-referenced data from Habitat Ecology Team's groundfish and habitat surveys. Goal is to be able to prioritize geographic areas for habitat-specific assessment methods, more effectively identify and protect EFH, and fill gaps in information on seafloor habitats and associated species.
- Use already-established baseline information (from 1997-98 surveys) to monitor Big Creek Ecological Reserve off central CA by conducting direct observation surveys of abundance, size structure, and diversity of groundfishes and their associated habitats. Collaborators (MLML, CDFG, CA Sea Grant, MB Natl Marine Sanctuary)
- Conduct study to determine time of settlement and growth from otolith microstructure of juvenile rockfishes already collected from several areas along California coast over the past 20 years.
- In situ surveys of juvenile rockfishes and their associations with mircroscale habitat features at nearshore study sites.
- Field-test improved laser line scan system to augment and calibrate conventional surveys of deepwater groundfishes, and to investigate fish-habitat associations. This system has been newly revised based on results from our 2001 field studies and is now ready for further evaluation as an advanced imaging technology for EFH and improved stock assessments. Collaborators (NWFSC; SAIC; NOAA NURP; NOAA Ocean Ex; Univ New Hampshire)
- Build ecosystem decision-support web-based tools to support and improve accessibility of EFH models developed for the west coast groundfish EIS. These tools will place the models and comprehensive databases in the hands of managers, which will greatly improve their decisions regarding EFH. Collaborators (NW Region; MRAG; Tetralogic Consulting; PFMC)

Early Life History Team

Introduction

Recruitment variability in marine fishes is generally thought to be a function of processes operating in the larval or early juvenile stages. Better understanding of these processes has tremendous value in predicting the abundance of an age cohort later in life (year-class strength), and for evaluating the potential impact of both natural and human-induced environmental changes on population dynamics. Despite extensive research efforts in this field in recent decades, definitive linkages between environmental patterns and larval/juvenile survival remain elusive. Complex interactions of spatial and temporal patterns in habitat quality, physical conditions, and the community structure of interacting species presumably contribute to the difficulty in resolving discrete causal relationships. The continuing threatened status of West Coast salmonid populations and declining abundance trends in several species of rockfishes warrant more intensive research into the array of factors driving early survival. Current projects focus on larval quality and growth rates as indicators of individual fitness. This individual variability provides the template on which mortality acts. The team's research attempts to

understand both the long-term evolutionary selection pressures that maintain individual variability and the short-term ecological consequences for determining year class strength.

Objectives

- Assess variability in fitness characteristics of individual larval rockfish and determine sources of variability
- Determine environmental factors influencing natural growth variability and adoption of contrasting life history trajectories in juvenile steelhead
- Identify essential fish habitat and functional quality of different habitats for newly settled rockfishes

Research and Management Support Activities

Fitness variability in larval rockfish - interspecific comparisons

Slight differences in the quality of larvae produced by female rockfish can potentially translate into major differences in early survival and future contribution to year class strength. This project uses laboratory experiments to examine fitness variability and potential life history trade-offs at both the intra- and inter- specific level. At the inter-specific level we hypothesize that trade-offs will exist in the initial size of larvae at parturition, bioenergetic condition as indexed by oil reserves, initial swimming capabilities, growth rates and mortality. Among species, variation in these traits ay be linked to adaptations related to the time of year when demonstrate marked differences among species. There is a clear trade-off between average spawning takes place. Preliminary results parturition) among the five species examined thus far (Figure 1). These patterns appear to be closely related to the peak timing of parturition for each species. Species that release larvae in early winter, such as black rockfish (*Sebastes melanops*) and blue rockfish (*S. mystinus*), have relatively small larvae but the larvae are well provisioned with relatively large oil globules. Larvae of species that spawn in late spring, such as gopher (*S. carnatus*) and kelp (*S. atrovirens*) rockfish have minimal oil reserves but are larger in overall body size. These alternate strategies are potentially explained as adaptive responses to larval size and average larval condition (indexed by the size of the oil globule present at oceanographic conditions at the time of extrusion. Larvae released in early winter, prior to the season of spring upwelling and enhanced productivity, may require high lipid stores to allow survival under potentially poor or sporadic eeding conditions. Larvae released during the upwelling season presumably have a more secure prey base but larger body size may enhance their swimming capabilities and reduce their susceptibility to predators or other threats.

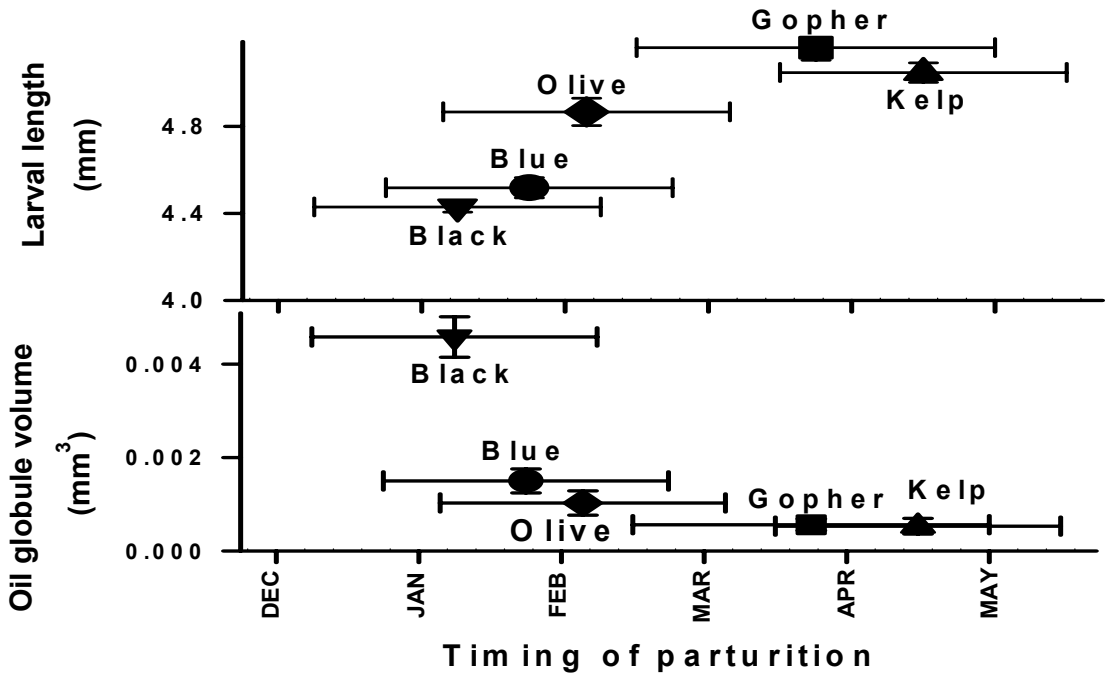

Figure 1. Mean length of larvae at parturition and mean oil globule size of 5 rockfish species compared to annual peak spawning period

Fitness variability in larval rockfish - intraspecific comparisons

At the intra-specific level, laboratory experiments are use to test the hypothesis that larval quality in rockfish is a function of female age, with older females producing progeny with a greater likelihood of survival than larvae from younger females. Pregnant females are collected in the field and held individually in aquarium tanks until they release larvae naturally. Samples of larvae are stocked in small holding tanks, where their growth and survival with and without food (live rotifers) is monitored. At parturition, larvae are analyzed for average notochord length and oil globule size, and behavioral responsiveness tested using a videocamera and image analysis system. Females are analyzed for size, body condition, and age (based on otoliths), and these traits are related to the various measures of larval quality. Prior studies have established a remarkable dependence of larval quality on maternal age in black rockfish, with older females producing larvae that growth 3 times as fast and stave off starvation twice as long compared to larvae produced by young females. Preliminary results suggest that blue rockfish, a species that spawns in early winter as do black rockfish, exhibit a similar increase in larval survival capabilities as maternal age increases (Figure 2). Results are less distinctive for species that

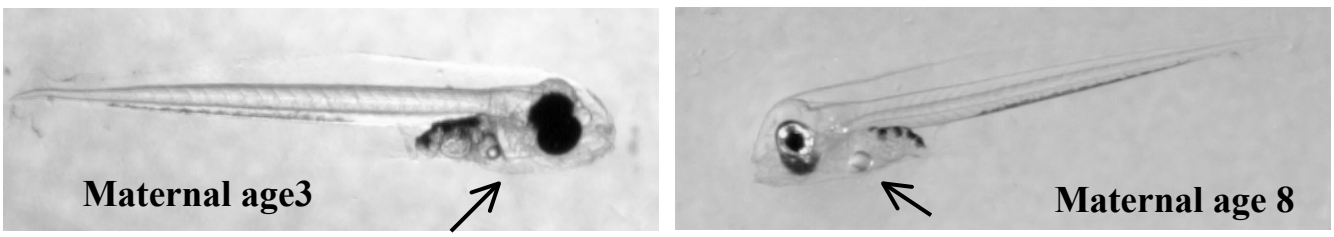

Figure 2. Contrast in oil globule size (arrows) at parturition for larval blue rockfish.

spawn later in the year and whose larvae appear to be less dependent on lipid energy stores provided in the oil globule by the female. These results have direct application to design and implementation of Marine Protected Areas. If larvae from older females are consistently of higher quality and have greater likelihood of survival, a diverse age distribution may be essential to long-term sustainability of rockfish populations. MPAs may be the only effective management approach that preserves the natural age distribution of adults in this long-lived guild of groundfishes.

Fitness variability in larval rockfish - paternal contribution

An additional laboratory experiment examining larval fitness addresses the hypothesis that paternal effects also influence larval quality and that females exhibit sexual selection of males in their mating behavior. All *Sebastes* species are livebearers with internal fertilization. Following copulation, females are able to store sperm and control when fertilization occurs. It is not currently known if females mate with more than one male, although unpublished genetic studies suggest this occurs. To address questions of multiple paternity, sexual selection, and differential paternal effects, mature kelp rockfish (8 males and 9 females) were collected prior to mating and held in a large pool for 2 months. All 9 females became pregnant during this time. One female appeared to resorb the larvae, but all others displayed normal larval development and parturition. Genetic analyses will be used to determine which of the 8 males fathered each female's progeny. Analysis of surviving larvae after two weeks of rearing will determine differential survival in any broods with multiple fathers. Fathers and mothers will be aged and their condition determined to examine correspondence of parental quality with larval quality, and to determine differential selection of mating partners.

Dispersal/ recruitment dynamics and pelagic juvenile rockfish swimming capabilities

Rockfishes remain in pelagic habitats following metamorphosis and spend 1-5 months in the water column prior to settlement. Their larger body size at this stage (20 to 60 mm) allows increased capacity for active swimming and control of their location in the open ocean, although swimming capabilities have not been previously tested for any pelagic stage rockfishes. This study focuses on species comparisons in a laboratory-swimming chamber to determine contrasting capabilities. Associated modeling studies are examining the potential effect of interspecific differences in swimming behavior on recruitment dynamics and settlement strategies of pelagic juvenile rockfishes. Pelagic juvenile rockfish obtained from the SWFSC annual pelagic juvenile trawl survey and from weekly collections in Monterey Bay by UCSC researchers are being tested for U-crit swimming speeds in an experimental swimming flume.

Essential Fish Habitat for newly settled juvenile rockfishes

The Sustainable Fisheries Act of 1996 requires fishery management plans to describe and identify essential fish habitat and minimize adverse effects on that habitat caused by fishing and other activities. Current efforts at describing EFH for rockfishes have focused on adult stages, for which substantial information is available from commercial logbooks, trawl surveys, and direct observations from ROVs and submersibles. However, even basic information on settlement habitats for young-of-the-year stages is unknown, particularly for those species that reside in outer shelf and slope habitats as adults, such as the overfished species that have engendered the rockfish crisis. For many marine species, the transition from the pelagic larval/juvenile stage to the benthic stage constitutes a population bottleneck. This field study is

testing the hypothesis that not all benthic habitats have equal value in promoting successful survival and growth of rockfish juveniles. A particular concern is that depth closures intended to protect adults may inadvertently shift trawling efforts to shallower habitats, with the resulting disturbance impacting important juvenile nurseries. The specific goals of this study are: 1) Sample a range of potential juvenile rockfish habitats to determine what habitats are used by juvenile rockfishes. 2) Back-calculate the age of rockfish juveniles captured among different habitats to determine if there is any evidence for sequential migration of developing juveniles among different habitat types. 3) Examine post-settlement growth rates, condition and gut contents of juveniles to determine if different habitats vary in terms of their quality as nursery habitats for juvenile rockfishes. Currently different gear types are being compared for their efficiency in capturing new settlers. Methods being tested include YOY collectors (or "SMURFS"), light traps, fish traps, minnow traps, gill nets and line fishing. In conjunction with development of suitable capture methods, visual surveys will be conducted using an underwater video camera. This project will fill a critical gap in our knowledge of the habitat requirements for recovering rockfish populations.

Determinants of life history strategy in Oncorhynchus mykiss

Steelhead exhibit a remarkable plasticity of life history trajectories, with substantial variability in timing of juvenile smoltification and emigration to the ocean, timing of maturation, and timing of adult return. Presumably maintaining this diversity of life histories is critical to the persistence of steelhead populations in a variable environment, and may be particularly important at the southern end of their range. The factors that determine life history trajectories are thought to include growth rates and condition (i.e. lipid storage), which are in turn affected by habitat quality (prey availability, temperature) and fish density. This project uses laboratory experiments to test for the influence of body size in the fall and discrete environmental factors on behavior during winter and likelihood of smoltification the following spring. Fish from local streams raised from the egg stage at the Monterey Bay Salmon and Trout Project hatchery on Scott Creek are brought to the Santa Cruz lab in late fall and divided into experimental treatments of body size (large and small tails of the available length distribution) and ration (ad libitum or near maintenance). Growth rates are monitored throughout the winter and spring, and behavior assessed by videotaping fish at night and during the day. In May, smoltification readiness is determined based on assays of Na^+, K^+-ATPase activity in gill filament tissue. Fish are also subjected to a seawater challenge to verify their readiness to migrate into nearshore habitats. Results thus far indicate a clear relation of both size and ration with fish behavior and impending smoltification. These results are being evaluated in a life history modeling framework through collaborative work with Marc Mangel, UCSC. Additional experiments initiated in 2004 will examine the role of parental life history types in influencing the life history trajectories of their progeny. In two sets of experiments, eggs from a single anadromous female were fertilized with sperm from anadromous males, jack (early returning) males, and resident males. We are currently monitoring growth of these different families and will determine seawater readiness based on gill enzyme analysis in the spring.

Analysis of growth patterns in wild juvenile steelhead

Life history strategies in steelhead are presumably dependent to a large extent on juvenile growth rates. Individuals not achieving a threshold size for smoltification may remain in fresh water for a second or third summer and emigrate to the ocean later in life or residualize and forgo emigration altogether. Laboratory studies have demonstrated a capacity for rapid growth rates, but growth under natural conditions is largely unknown for California populations of steelhead. This field based study involves tracking growth and movement patterns in a natural population of steelhead in Soquel Creek, in cooperation with the Soquel Demonstration State Forest. In 2002, we began assisting with SDSF fall electroshock sampling at four creek sites, conducted since 1993. We have added another site and extended the work to earlier in the summer and later in the fall/winter to allow a better picture of temporal changes within a year. In 2003, the five locations will be sampled in early summer, early fall, and late fall or winter. All fish collected in June are marked with either elastomer tags (fish < 70 mm TL) or PIT tags (fish > 70 mm). Recaptures of these fish in September and again in December allow examination of growth and provide some indication of movement and mortality patterns. Scale analysis is used to verify fish ages. The time series thus far has exhibited high site consistency in fish density and the proportion of the catch comprised of age-0 fish, as well as apparent density-dependent effects on growth, survival, and life history trajectories. At locations with high density, growth is slow and survival of age-0 fish remaining in the stream also appears to be low, assuming that their absence a year later is due to mortality and not emigration. Sites with low density have faster growth rates, and the presence of a relatively high number of age-1+ fish in the following year suggests higher survival of age-0 fish that remain in the stream. Recaptures of tagged fish reveal two major patterns: summer growth is extremely low for all fish, and growth in general decreases as fish size increases (Figure 3). Growth does not improve in the fall when water temperatures have declined but flow rates remain at very low levels, suggesting that food availability rather than warm temperatures underly the poor summer growth rates. Recaptures of PIT tagged fish in June 2004 indicate much faster growth rates in the winter period. Recaptures also suggest a higher site fidelity for individuals residing in low density sites.

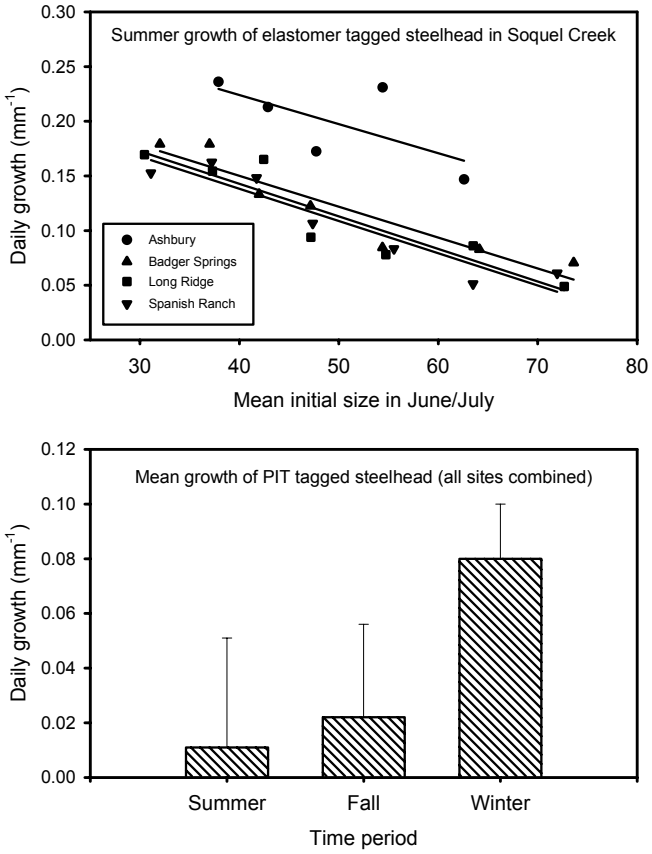

Figure 3. Upper: Mean growth rates of elastomer tagged steelhead during summer at 4 sites in Soquel Creek. Ashbury has a low density of fish present, whereas the other 3 sites have very high densities. Lower: Mean growth during summer, fall, and winter for PIT tagged steelhead in Soquel Creek, all sites combined

Growth variability in early life stages of sablefish

Sablefish, *Anoplopoma fimbria*, are a vital and valuable component of commercial fisheries from California to Alaska. Like many west coast groundfish species, they are long lived, with the fishery sustained by occasional exceptional year classes. We hypothesize that variability in year class strength is driven by bottom up processes underlying physical factors that control variability in survival during critical early larval stages. Prior studies have demonstrated a unique capacity for rapid growth by larvae and early juveniles and behavioral studies suggest that fast growth may be essential for early survival. This project uses otoliths of field collected larvae and juveniles to estimate growth rates and examine linkages between growth and oceanographic conditions.

Accomplishments

Publications

- Hurst, T.P., M.L. Spencer, S.M. Sogard, and A.W. Stoner. In press. Compensatory growth, energy storage and behavior of juvenile Pacific halibut *Hippoglossus stenolepis* following a thermally induced growth reduction. Mar. Ecol. Prog. Ser.
- Fisher, R. In press. Swimming speeds of larval coral reef fishes: impacts on self-recruitment and dispersal. Mar. Ecol. Prog. Ser.
- Fisher, R. and S.K. Wilson. In press. Maximum sustainable swimming speeds of nine species of late stage larval reef fishes. J. Exp. Mar. Biol. Ecol.
- Fisher, R. In press. Nocturnal vertical distribution of late-stage larval coral reef fishes off the leeward side of Lizard Island, Great Barrier Reef, Australia. Bull. Mar. Sci.
- Berkeley, S.A., C. Chapman, and S.M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. Ecology 85:1258-1264.
- Sogard, S.M. and M.L. Spencer. 2004. Energy allocation in juvenile sablefish: effects of temperature, ration and body size. J. Fish Biol. 64:726-738.
- Green, B. and R. Fisher. 2004. Temperature influences swimming speed, growth and larval duration in coral reef fish larvae. J. Exp. Mar. Biol. Ecol. 299: 115-132.
- Duffy-Anderson, J., L. Ciannelli, T. Honkalehto, K.M. Bailey, S.M. Sogard, A.M. Springer, and T. Buckley. 2003. Distribution of age-1 and age-2 walleye pollock in the Gulf of Alaska and eastern Bering Sea: sources of variation and implications for higher trophic levels. In: The Big Fish Bang: Proceedings of the 26th Annual Larval Fish Conference, H.I. Browman and A.B. Skiftesvik (eds).
- Sogard, S.M. and B.L. Olla. 2002. Contrasts in the capacity and underlying mechanisms for compensatory growth in two pelagic marine fishes. Mar. Ecol. Prog. Ser. 243:165-177.

Presentations

- 3rd International Symposium on Fish Otolith Research and Application, Townsville, Australia, July 2004 (Sogard).
- Coral Reef Symposium, Okinawa, Japan, July 2004 (Fisher).
- Annual Environmental Leadership Forum, STEPS (Science, Technology, Engineering, Policy, and Society) Institution for Innovation in Environmental Research, University of California, Santa Cruz, CA, June 2004 (Invited, Sogard).

- Symposium on Central Valley steelhead recovery, AFS Cal-Neva meeting, Redding, CA, April 2004 (Invited, Sogard).
- Western Groundfish Conference, Victoria, BC, February 2004 (Berkeley, Sogard, and Fisher).
- Early Life History Section/ Larval Fish Conference, Bergen, Norway, July 2002 (Sogard, Fisher).

Committees and Service

- Program Chair, 27th Annual Larval Fish Conference, Early Life History Section, American Fisheries Society, Santa Cruz, CA, August 2003
- Science Advisory Group, Interagency Ecology Program for analysis of the Sacramento-San Joaquin Estuary, 2003-2004.
- Technical Oversight Committee, Monterey Bay Salmon and Trout Project, 2003-2004.
- Graduate student committees, 5 Ph.D. students at Oregon State University, 1 M.S. student at the University of Delaware, 1 M.S. student at the University of South Alabama.
- Mentor for 3 undergraduate students in NOAA sponsored internship program with the Earth Systems Science and Policy department of CSUMB, 2003-2004.
- Advisor to UCSC undergraduate student conducting senior thesis research on life history strategies and smoltification patterns in steelhead.

Extramural Research Support

NOAA's Essential Fish Habitat program, $75K in 2003, $68K in 2004

Future Research Directions

- Expand studies of larval rockfish quality to determine both intraspecific maternal age effects and interspecific differences across a greater range of species

- Continue and expand EFH studies of newly settled rockfishes, incorporating new video techniques to enhance in situ identification of YOY fishes and provide improved resolution of settlement habitats.

- Continue the time series of growth and movement data in natural populations of steelhead using tagging studies in Soquel Creek.

- Develop further experimental methods to assess the role of parental life history (anadromous vs. non-anadromous fathers and mothers) on growth and smoltification of juvenile steelhead.

APPENDIX A

PUBLICATIONS OF THE SANTA CRUZ LABORATORY

2002 - 2004

CURRICULUM VITAE

NAME: PETER B. ADAMS

PRESENT POSITION: Research Fishery Biologist, Fisheries Branch Chief

EDUCATION: Ph.D., Ecology, University of California, Davis, 1988; M.S., Ecology, University of California, Davis, 1973; B.S., Biology, University of Redlands, 1970.

PAST EXPERIENCE:

1995–present	Research Advisor National Research Council, Research Associateship Program Washington, DC
1976–present	Research Fishery Biologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California

RESEARCH INTERESTS: Modeling of populations and communities; ESA risk assessment; dynamics of exploited populations; statistical analysis, particularly sampling, and line transect population estimates.

HONORS AND AWARDS: Performance Awards, NOAA Fisheries, 2002, 2000, 1999, 1998, 1996, 1994, 1992; Bronze Medal, U.S. Department of Commerce, 2003; Outstanding Publication Award, *Fishery Bulletin*, NOAA Fisheries, 1980; Jastro-Shields Graduate Research Scholarship, University of California, Davis, 1974–1975; Magna Cum Laude, University of Redlands, 1970.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Biological Review Team (Chair), Green Sturgeon, NOAA Fisheries, 2002–present; Biological Review Team, West Coast salmonids, NOAA Fisheries, 1996–present.

SELECTED PUBLICATIONS:

Adams, P. B., C. B. Grimes, S. T. Lindley, and M. L. Moser. 2002. Status review for North American green sturgeon, *Acipenser medirostris*. U.S. Department of Commerce, NOAA, NMFS, SWFSC, Santa Cruz, CA. 50 p.

Adams, P. B., E. H. Williams, K. R. Silberberg and T. E. Laidig. 1999. Southern lingcod stock assessment in 1999. *In:* Appendix to Status of the Pacific coast groundfish fishery through 1999 and recommended acceptable biological catches for 2000. Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, Portland, Oregon. 79 p.

Adams, P. B., M. J. Bowers, H. E. Fish, T. E. Laidig, and K. R. Silberberg. 1999. Historical and current presence-absence of coho salmon (*Oncorhynchus kisutch*) in the Central California coast evolutionarily significant unit. U.S. Department of Commerce, NOAA, NMFS, SWFSC, Administrative Report SC-99-02. 26 p.

Adams, P. B. and D. F. Howard. 1996. Natural mortality of blue rockfish *Sebastes mystinus* during their first year in nearshore benthic habitats. Fishery Bulletin 94:156–162.

Adams, P. B., J. H. Butler, C. H. Baxter, T. E. Laidig, K. Dahlin, and W. W. Wakefield. 1995. Population estimates of Pacific coast groundfishes from video transects and swept-area trawls. Fishery Bulletin 93:446–455.

Adams, P. B. 1980. Life history patterns in marine fishes and their consequences for fisheries management. Fishery Bulletin 78:1–12.

Lenarz, W. H. and P. B. Adams. 1980. Some statistical considerations of the design of trawl surveys for rockfish (Scorpaenidae). Fishery Bulletin 78:659–674.

CURRICULUM VITAE

NAME: ANDRES AGUILAR

PRESENT POSITION: UC President's Postdoctoral Fellow

EDUCATION: PhD. in Biology, University of California, Los Angeles, 2003; B.A. in Biology, Humboldt State University (Cum Laude), 1997.

PAST EXPERIENCE:

2003-present	Postdoctoral Fellow Molecular Ecology Team/Dept. of Ocean Sciences NMFS/UCSC Santa Cruz, CA
1998-2002	Teaching Assistant University of California, Los Angeles Los Angeles, CA

RESEARCH INTERESTS: Marine fisheries, population genetics, molecular evolution, phylogeny, statistical detection of selection on genetic data, evolution of immune system genes.

HONORS AND AWARDS: University of California President's Postdoctoral Fellowship, 2003; UCLA Dissertation Year Fellowship, 2002; NSF Doctoral Dissertation Improvement Grant, 2002; Outstanding Graduate Student Oral Presentation: Annual Meeting of the Society for the Advancement of Chicanos and Native Americans in Sciences, 2002.

SELECTED PUBLICATIONS:

Aguilar A., Banks J., Levine K., Wayne R.K. (in press) Population genetics of Northern pike (*Esox lucius*) introduced to Lake Davis, CA. Can. J. Fish. Aquat. Sci.

Aguilar A., Edwards S.V., Smith T.B., Wayne R.K. (in review). Low polymorphism in the peptide binding region of a MHC class II gene in the Little Greenbul (*Andropadus virens*), with comments on MHC evolution in birds. J. Heredity.

Aguilar A., Roemer G., Debeham S., Binns M., Garcelon D.,Wayne R.K. 2004. High MHC diversity maintained in an otherwise genetically monomorphic mammal. Proc. Natl. Acad. Sci. USA. 101: 3490-3494.

CURRICULUM VITAE

NAME: ARNOLD J. AMMANN

PRESENT POSITION: Research Fishery Biologist, Southwestern Fisheries Science Center

EDUCATION: Masters Degree from University of California at Santa Cruz, CA 2001; Bachelors Degree from University of California at Santa Barbara, CA 1994

PAST EXPERIENCE:

2002	Post-graduate Researcher Partnership for Interdisciplinary Studies of Coastal Oceans University of California Santa Cruz, CA
1998 - 2002	Research Assistant Partnership for Interdisciplinary Studies of Coastal Oceans University of California Santa Cruz, CA
1995 - 1998	Laboratory Assistant II Ecology of fish on natural reefs and oil/gas production platforms Marine Science Institute Santa Barbara, CA
1995	Research Technician Long-Term Ecological Research Project UC Santa Barbara R/V Polar Duke, Antarctica
1994	Research Technician GS-5 Kelp Forest Monitoring Project Channel Islands National Park Service Ventura, CA

RESEARCH INTERESTS: Population and recruitment dynamics of fishes, biological oceanography

HONORS AND AWARDS: Friends of the Long Marine Laboratory Award 2000 and 2001; Myers Oceanography and Marine Biology Trust Award 1999

SELECTED PUBLICATIONS:

Ammann, A.J. 2003 SMURFs: standard monitoring units for the recruitment of temperate reef fishes. J. Exp. Mar. Bio. Ecol. 299:135-154.

Ammann, A.J. and Carr, M.H. 2000. In: *Ecosystem Observations for the Monterey Bay National Marine Sanctuary:* Contrasting effects of La Nina and El Nino on recruitment of juvenile rockfish. pp. 11-12

Ammann, A.J.; Shroeder D.M.; and Love M. In: *Ecological role of natural reefs and oil and bas production platforms on rocky reef fishes in southern California*: Abundance, biomass, and egg production of kelp bass (*Paralabrax clathratus*) inside and outside marine reserves at Santa Catalina Island, California. USGS/BRD/CR 1999-0007 pp. SB-1 to SB-3

CURRICULUM VITAE

NAME: ERIC C. ANDERSON

PRESENT POSITION: Research Molecular Geneticist

EDUCATION: Ph.D. in quantitative ecology and resource management, August 2001, University of Washington, Seattle, Washington; M.S. in fisheries, June 1998, University of Washington, Seattle, Washington; B.A. (with distinction) in human biology, June 1993, Stanford University, Stanford, CA.

PAST EXPERIENCE:

2003-present	Research Molecular Geneticist NMFS/NOAA/SWFSC Santa Cruz, CA
2001-2003	Postdoctoral Researcher Dept. of Integrative Biology University of California Berkeley, CA

RESEARCH INTERESTS: Population genetics, statistical genetics. Inference of effective population size, pairwise relatedness, and population structure with molecular markers. Markov chain Monte Carlo methods. Detecting natural selection. Genetic basis of phenotypic traits.

HONORS AND AWARDS: Phi Beta Kappa, Stanford University, 1993. Best student paper, WNAR Biometrics Society, 2000.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: NMFS South-Central California Technical Recovery Team (2003-present).

SELECTED PUBLICATIONS:

Anderson, E.C. and K.K. Dunham. (submitted). Spip 1.0: A program for simulating pedigrees and genetic data in age-structured populations. Mol. Ecol. Notes.

Garza, J.C. and E.C. Anderson (submitted). Estimation of population size with molecular markers. Mol. Ecol.

Anderson, E.C. and M. Slatkin. 2004. Population genetic basis of haplotype blocks in the 5q31 region. Am. J. Hum. Genet. 74:40-49.

Anderson, E.C. and J. Novembre. 2003. Finding haplotype block boundaries by using the minimum description length criterion. Am. J. Hum. Genet. 73:336–354.

Anderson, E.C. and M. Slatkin. 2003. Orr's quantitative trait loci sign test under conditions of trait ascertainment. Genetics 165:445-446.

Anderson, E.C. and E.A. Thompson. 2002. A model-based method for identifying species hybrids using multilocus genetic data. Genetics 160:1217–1229.

Anderson, E.C. and P.A. Scheet. 2001. Improving the estimation of bacterial allele frequencies. Genetics 158:1383–1386.

Anderson, E.C., E.G. Williamson, and E.A. Thompson. 2000. Monte Carlo evaluation of the likelihood for Ne from temporally-spaced samples. Genetics 156:2109–2118.

CURRICULUM VITAE

NAME: TARA ANDERSON

PRESENT POSITION: Post Doctoral Fellow

EDUCATION: PhD, Melbourne University, Australia, 2003; MSc, Zoology, Auckland University, New Zealand, 1994; BSc, Biology, Auckland University, New Zealand, 1991.

PAST EXPERIENCE:

2001-present	Post Doctoral Fellow Joint NMFS/SWFSC and USGS Menlo park. Santa Cruz, California
1996 - 1997	Fishery Scientist Australian Institute of Marine Sciences Townsville, Queensland, Australia.
1994 - 1996	Senior Research Assistant Marine Biology Department, James Cook University Townsville, Queensland, Australia.

RESEARCH INTERESTS: Organism-habitat relationships, measuring spatial pattern from large scale landscapes and habitat mosaics down to fine-scale microhabitat associations, groundfish distribution patterns, habitat mapping, fish-seagrass associations.

HONORS AND AWARDS: Australian Postgraduate Award 1997-2000. Australian Interstate Student Award 1997. AMSA Biology Travel Award 1997. New Zealand Graduate Scholarship 1992-94. New Zealand Society of Arts Scholarship 1988.

SELECTED PUBLICATIONS:

Anderson, T.J., Cochran, G.R., Robert, D.A., Chezar, H., and Hatcher, G. (*in review*). A systematic real-time method to characterize seafloor habitats and benthic macro-organisms: Habitat mapping with a side-scan sonar and towed camera-sled. *submission to Geohab2004*.

Anderson, T. J., M. M. Yoklavich, and S. L. Eittreim. (*in press*). Linking fine-scale groundfish distributions with large-scale seafloor maps: issues and challenges of combining biological and geological data. *In*: P. W. Barnes and J. P. Thomas, editors. *Benthic habitats and the effects of fishing*. American Fisheries Society, Symposium 41, Bethesda, Maryland.

Anderson, T.J. (1999). Morphology and biology of *Octopus maorum* Hutton 1880 in northern New Zealand. Bulletin of Marine Science 65(3): 657-676.

Anderson, T.J. Babcock, R. (1999). Subcutaneous electromagnetic tagging of benthic octopus: a preliminary evaluation. Marine and Freshwater Research 50:225-227.

Anderson, T.J. (1997). Factors influencing habitat association and shelter use of *Octopus tetricus*. Marine Ecology Progress Series 150:137-148.

CURRICULUM VITAE

NAME: BAISHALI BAKSHI

PRESENT POSITION: Postdoctoral researcher in Economics, NMFS, Santa Cruz Laboratory.

EDUCATION: Ph.D., Economics, University of California - Irvine, 2004; M.A., Economics, Delhi School of Economics, Delhi, India, 1999; B. Sc., Economics, Presidency College, University of Calcutta, India, 1997.

PAST EXPERIENCE:

2004-present	Postdoctoral researcher in Economics NMFS/ SWFSC Santa Cruz, California
Summer 2003	Instructor, Environmental Economics Writing Economics Department, University of California, Irvine
Summer 2001	Research Assistant School of Social Ecology and Economics Department, University of California, Irvine

RESEARCH INTERESTS: Resource management under uncertainty, Role of international trade in sustainable management of environmental resources, Corruption and resource use, Trade in electronic waste, Sustainable forest management and global warming, Asymmetric information in monitoring pollution and waste generation.

HONORS AND AWARDS: Summer Fellowship, School of Social Sciences, UC Irvine, Summer 2003; Dissertation Fellowship, School of Social Sciences, UC Irvine, Fall 2002; Summer Fellowship, Economics Department, UC Irvine, Summer 2002; Regents Fellowship, School of Social Sciences, UC Irvine, Fall 1999-Spring 2001; Junior Research Fellowship, Indian Statistical Institute, India, 1999.

SELECTED PUBLICATIONS:

Saphores, J. D. and B. Bakshi, 2001. Global Warming, Forests, and Biodiversity. *Energy Studies Review*, 10(1): 49-56, 2001.

Bakshi, B. and J.D. Saphores. In review. Grandma or the Wolf? A Real Options Framework for Managing Human-Wildlife Conflicts. Journal of Environmental Economics and Management.

Ranjan, P. and B. Bakshi. In review. Corruption, Environmental Resources, and International Trade. Journal of Development Economics.

Bakshi, B. International Trade in Natural Resources and the Heckscher-Ohlin Model: The Role of Corruption.

CURRICULUM VITAE

NAME: KENNETH A. BALTZ

PRESENT POSITION: Oceanographer, Groundfish Population Analysis Team

EDUCATION: M.S., Physical Oceanography, Naval Postgraduate School, 1997; B.S., Marine Biology, Florida Institute of Technology, 1987.

PAST EXPERIENCE:

1999-2000	Computer Specialist Information Technology Services, NOAA/NMFS Santa Cruz/Tiburon Laboratory
1997-1999	Field Operations Officer NOAA Ship CHAPMAN and NOAA Ship GORDON GUNTER Office of NOAA Corps Operations and NMFS SEFSC Pascagoula, MS
1993-1997	Fisheries Oceanographer (Research and Databases Support) NMFS/SWFSC Tiburon, California (93-95) and Pacific Grove, CA (95-97)
1991-1993	Navigation and Field Operations Officer NOAA Ship Townsend Cromwell Office of NOAA Corps Operations and NMFS SWFSC, Honolulu, HI
1989-1990	Environmental/Ecology Educator and Charter Boat Captain Marine Sciences Under Sails, Hollywood, FL
1987-1989	Animal Trainer for Orcas Sea World of Florida, Orlando, FL

RESEARCH INTERESTS: Pacific Groundfish, Physical Oceanographic Impacts to Fisheries, California Current.

HONORS AND AWARDS: National Defense Service Medal, 2003; Coast Guard Reserve Medal (Mobilized), 2002; Coast Guard Meritorious Unit Commendation, 2002; NOAA Special Achievement Awards, 1994 & 1996; Pacific Service Ribbon, 1993; Beta Beta Beta Biological Honor Society.

SELECTED PUBLICATIONS:

Baltz, K.B. 1997. Ten years of hydrographic variability off central California during the upwelling season. Naval Postgraduate School Technical Rep., NPS-OC-97-008, 319p.

Schwing, F.B., T.L. Hayward, K.A. Baltz, T. Murphree, K.M. Sakuma, A.S. Mascarenas Jr., A.W. Mantyla, S.I. Castillo, S.L. Cummings, D.G. Ainley, and F. Chavez. 1997. The state of the California Current, 1996-1997: mixed signals from the tropics. CalCOFI Reports, Vol. 38.

Sakuma, K.M., F.B. Schwing, K.A. Baltz, D. Roberts, S. Ralston. 1997.
The physical oceanography off the central California coast during May-June, 1996: a summary of CTD data from pelagic juvenile rockfish surveys. U.S. Dept. of Commerce. NOAA-TM-NMFS-SWFSC-246, 155p.

Schwing, F.B., M. O'Farrell, J.M. Steger, K.A. Baltz.1996. Coastal upwelling indices, west coast of North America, 1946-95. U.S. Dept. of Commerce. NOAA-TM-NMFS-SWFSC-231, 207p.

Sakuma, K.M., F.B. Schwing, K.A. Baltz, D. Roberts, H.A. Parker, S. Ralston. 1996. The physical oceanography off the central California coast during May-June, 1995: a summary of CTD data from pelagic juvenile rockfish surveys. U.S. Dept. of Commerce. NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-232, 144p.

CURRICULUM VITAE

NAME: RACHEL C. BARNETT-JOHNSON

PRESENT POSITION: Research Fishery Biologist- Student Career Experience Program

EDUCATION: Ph.D. candidate, Ecology and Evolutionary Biology, University of California, Santa Cruz; B.A., Biology, Wellesley College, Massachusetts, 1997.

PAST EXPERIENCE:

1999 - present	Graduate Researcher
1999 - 2000	Teaching Assistant University of California, Santa Cruz
1998	Zooplankton Identification Specialist SWFSC Antarctic Marine Living Resources Group South Shetland Islands, Antarctica
1998	Taxonomist California Academy of Sciences San Francisco, California
1997	Tropical Marine Ecologist/ Instructor International Zoological Expedition Belize, Central America
1995 - 1997	Marine Biology Teaching Assistant Wellesley College, Massachusetts

RESEARCH INTERESTS: Applied marine ecology, population biology, fishery ecology, metapopulation dynamics, and application of stable isotopes as tracers of spatial structure in populations.

HONORS AND AWARDS: Best Student Presentation, Third International Symposium Fish Otolith Research and Application (2004); UC Marine Council Fellowship (2002-2004); Myers Oceanographic and Marine Biology Scholarship (2001); Honorable Mention, NSF Graduate Research Fellowship (1998 & 1999).

SELECTED PUBLICATIONS:

Barnett-Johnson. Sources of Salmon. *In PISCO Coastal Connections 2004*: 3:13.

Barnett-Johnson, R.C., Ramos, F.C., MacFarlane, R.B.,and C.B.Grimes. (In review). Identifying the natal origin and migration history of adult salmon using Sr isotopes in otoliths by laser ablation MC-ICPMS. *Canadian Journal of Fisheries and Aquatic Sciences.*

Jensen, G.C. and R.C. Johnson. 1999. Reinstatement and further description of *Eualus subtilis* Carvacho & Olsen, and comparison with *E. lineatus* Wicksten & Butler (Crustacea: Decapoda: Hippolytidae). *Proceeding of the Biological Society of Washington* 112(1): 133-140.

Barnett-Johnson, R.C., Grimes, C.B., Royer, C.F. and C.J.Donohoe (In Prep). Discrimination of hatchery and wild chinook salmon (Onchorynchus tshawysha) in the California Central Valley using otolith microstructure.

CURRICULUM VITAE

NAME: ERIC P. BJORKSTEDT

PRESENT POSITION: Research Fishery Biologist, Salmon Population Analysis Team

EDUCATION: Ph.D., Biological Sciences (Ecology), Stanford University, 1998; B.A. (with Honors), Biology and English, University of Delaware, 1992.

PAST EXPERIENCE:

2001–present	Adjunct Professor Humboldt State University, Department of Fisheries Arcata, California
1998–present	Research Fishery Biologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1998	NRC Postdoctoral Research Associate NOAA Fisheries, Northwest Fisheries Science Center Seattle, Washington

RESEARCH INTERESTS: Population and metapopulation dynamics of anadromous salmonids; biological and physical processes affecting recruitment and population structure in coastal marine fishes; application of remote sensing in ecological research; life history evolution and behavioral ecology of marine and anadromous fish; theoretical and statistical ecology.

HONORS AND AWARDS: Bronze Medal, U.S. Department of Commerce, 2003, 2000; Performance Award, NOAA Fisheries, 2000; Postdoctoral Research Associateship, National Research Council, 1998; Excellence in Teaching Award, Department of Biological Sciences, Stanford University, 1997, 1995; Norman K. Wessels Award for Outstanding Performance as a Teaching Assistant, Stanford University, 1994; Graduate Research Fellowship, National Science Foundation, 1993; Phi Beta Kappa, University of Delaware, 1991.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Technical Recovery Team (Chair), North-Central California Coast salmonids, NOAA Fisheries, 2001–present; Biological Review Team, West Coast salmonids, NOAA Fisheries, 2001–present.

SELECTED PUBLICATIONS:

Armsworth, P. R., C. V. Kappel, F. Micheli, and E. P. Bjorkstedt. Submitted. Working seascapes: the protection of endangered species and the conservation of biodiversity in marine ecosystems. To appear in: J.M. Scott, D.D. Goble, F. Davis, and G.Heal, editors. The Endangered Species Act at 30: Lessons and Prospects.

Bjorkstedt, E. P., L. K. Rosenfeld, B. A. Grantham, Y. Shkedy, and J. Roughgarden. 2002. Distributions of larval rockfish (*Sebastes* spp.) across nearshore fronts in a coastal upwelling region. Marine Ecol. Prog. Ser. 242:215–228.

Bjorkstedt, E. P. 2000. DARR (Darroch Analysis with Rank-Reduction): A method for analysis of stratified mark-recapture data from small populations, with application to estimating abundance of smolts from outmigrant trap data. U.S. Department of Commerce, NOAA, NMFS, SWFSC, Administrative Report, Santa Cruz, SC-00-02. 28 p.

McElhany P., Ruckelshaus M., Ford M. J., Wainwright T., Bjorkstedt E. P. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42, 156 p.

Bjorkstedt, E. P. 2000. Stock-recruitment relationships for life cycles that exhibit concurrent density dependence. Canadian Journal of Fishery and Aquatic Sciences 57(2):459–467.

CURRICULUM VITAE

NAME: SCOTT M. BLANKENSHIP

PRESENT POSITION: Postdoctoral Research Associate

EDUCATION: PhD. in Genetics, University of California, Davis. 2001; B.A. in biology, 1993, California Polytechnic State University, San Luis Obispo.

PAST EXPERIENCE: 2003-present Postdoctoral Research Associate
Molecular Ecology Team
NMFS/UCSC
Santa Cruz, CA

RESEARCH INTERESTS: Marine fisheries, molecular evolution, population genetics, microsatellites.

SELECTED PUBLICATIONS:

Blankenship S.M., May B., Hedgecock D. 2002. Evolution of a perfect simple-sequence-repeat locus in the context of its flanking sequence. Mol. Biol. Evol. 19: 1943-1951

Hedgcock D., Banks M.A., Rashbrook V.K., Dean C.A., Blankenship S.M. 2001. Applications of population genetics to conservation of chinook salmon diversity in the Central Valley. In: Brown, RL, editor. Fish Bulletin 179: Contributions to the Biology of Central Valley Salmonids. Sacramento (CA): California Department of Fish and Game.

Banks M.A., Blouin M.S., Baldwin B.A., Rashbrook V.K., Fitzgerald H.A., Blankenship S.M., and HedgecockD. 1999. Isolation and inheritance of novel microsatellites in chinook salmon (*Oncorhynchus tschawytscha*). Journal of Heredity 90: 281-288

CURRICULUM VITAE

NAME: DAVID A. BOUGHTON

PRESENT POSITION: Research Ecologist, Salmon Population Analysis Team

EDUCATION: Ph.D., Ecology, University of Texas, Austin, 1998; A.B. (magna cum laude), Ecology and Systematics, Cornell University, 1988.

PAST EXPERIENCE:

2001–present	Research Ecologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1999–2001	Research Ecologist U.S. Forest Service, Pacific N.W. Research Station Corvallis, Oregon
1998–1999	Ecologist U.S. EPA, Office of Research and Development Research Triangle Park, North Carolina
1988–1991	Programmer/Taxonomist Ichthyology, California Academy of Sciences San Francisco, California

RESEARCH INTERESTS: Population and metapopulation dynamics; local adaptation of animal behavior and life history, especially dispersal systems; complex life histories; landscape ecology.

HONORS AND AWARDS: Bronze Medal, U.S. Department of Commerce, 2003; Science Findings Award, U.S. Department of Agriculture, 2001; International Postdoctoral Fellowship, National Science Foundation, 1998; Buell Award (honorable mention), Ecological Society of America, 1998; Sigma Xi, University of Texas, 1997; STAR Fellow, U.S. Environmental Protection Agency, 1996; Dissertation Improvement Grant, National Science Foundation, 1995; Predoctoral Fellowship, National Science Foundation, 1991; Distinction in all subjects, Cornell University, 1988.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Technical Recovery Team (Chair), South-Central California Coast salmonids, NOAA Fisheries, 2003–present; Steering Committee, California Coastal Salmonid Monitoring Plan, NOAA Fisheries, 2003–present; Biological Review Team, West Coast salmonids, NOAA Fisheries, 2003–present; Modelling Workgroup, Survey and Manage Program, U.S. Department of Agriculture, 1999–2000.

SELECTED PUBLICATIONS:

Boughton, D.A. In press. South-Central California steelhead; Southern California steelhead. Pages B106–B122 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead, West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.

Boughton, D.A. & U. Malvadkar. 2002. Extinction risk in successional landscapes subject to catastrophic disturbances. Conservation Ecology 6(2):2.

Boughton, D.A. 1999. Empirical evidence for source-sink dynamics in a butterfly: Temporal barriers and alternative states. Ecology 80(8):2727–2739.

Boughton, D.A., B.B. Collette & A.R. McCune. 1991. Heterochrony in jaw morphology of needlefishes (Belonidae: Teleostei). Systematic Zoology 40(3):329–354.

CURRICULUM VITAE

NAME: MIGUEL CASTRENCE

PRESENT POSITION: Research Assistant, Fisheries Economics

EDUCATION: M.A., Geographic Information Sciences, Clark University, 2002; M.A., International Policy Studies, Monterey Institute of International Studies, 1996; B.A., Spanish Literature, University of Maryland, 1993.

PAST EXPERIENCE:

2004-present	Research Assistant NMFS/SWFSC, Santa Cruz, California
2003	Researcher and Technical Consultant Environmental Legal Assistance Center and Conservation International Puerto Princesa, Palawan, Philippines
2002	Graduate Student Researcher Marine Protected Areas Research Project,Visayas, Philippines
2001-2002	GIS Lab Manager Clark University, Worcester, Massachusetts
2001	Program Assistant World Resources Institute/Biological Resources Program/ Coastal and Marine Projects, Washington, DC
2000	Research and Administrative Assistant Peace Corps/Office of Special Services, Washington, DC
1998-1999	Community Forestry Extensionist Peace Corps, Guajiquiro Biological Reserve, Honduras
1996-1997	AmeriCorps Volunteer Bureau of Land Management, Fort Ord, California
1995-1996	Computer Lab Manager Monterey Institute of International Studies, Monterey, California

RESEARCH INTERESTS: Coastal resource management, protected areas, GIS capacity building and technical assistance, integrating social and natural sciences through GIS/remote sensing analyses

HONORS AND AWARDS: US Department of State/Fulbright scholarship, 2002; World Bank-United Nations Development Programme/Philippine Development Innovation Marketplace grantee, 2003

PUBLICATIONS:

Gjertsen, H. and M. Castrence. In prep. Identifying factors of success for community-based marine protected areas in the Visayas, Philippines.

Komwa, M. and M. Castrence. 2004. Utilizing nonspectral ancillary data to enhance image classification of Southeastern Malawi. 100th American Association of Geographers Annual Meeting, Philadelphia, Pennsylvania.

Wong, G. and M. Castrence. 2003. An integrated approach to modeling the risk of forest loss in southern Palawan. Palawan Corridor Strategy Development Project/Biodiversity Convention, Puerto Princesa, Palawan, Philippines.

Castrence, M.·2003. Rapid coral reef assessment with remote sensing: Local spatial autocorrelation in Landsat ETM+ imagery as an indicator of ecosystem health. 2nd International Tropical Marine Ecosystems Management Symposium, Manila, Philippines.

CURRICULUM VITAE

NAME: ANTHONY J. CLEMENTO III

PRESENT POSITION: Genetic Research Associate

EDUCATION: M.S. in Fisheries, Humboldt State University 2004; B.A. in Biology, Brown University 1996.

PAST EXPERIENCE:

2003-present	Genetic Research Associate Molecular Ecology Team NMFS/JIMO Santa Cruz, CA
2001-2003	Student Research Assistant Humboldt State University Arcata, CA
1998-2000	Scientific Aid CA Department of Fish and Game Willits, CA

RESEARCH INTERESTS: Identification of genetic basis of life history variation in salmonids; application of molecular genetic techniques to endangered species management and conservation.

HONORS AND AWARDS: Accepted to PhD program in Ocean Sciences at UCSC, 2004: UCSC Regent's Fellowship, 2004: Zumbrum Memorial Fellowship for Graduate Research, HSU, 2002; Marin Rod and Gun Club Scholarship, HSU, 2002.

SELECTED PUBLICATIONS:

Clemento, A.J. 2004. Discerning steelhead *(Oncorhynchus mykiss)* subpopulation structure in the Middle Fork Eel River using microsatellites. M.S. Thesis Humboldt State University.

CURRICULUM VITAE

NAME: CHERYL DEAN

PRESENT POSITION: Genetic Research Associate

EDUCATION: B.A. (with honors) in biology, 1993, California Polytechnic State University, San Luis Obispo.

PAST EXPERIENCE:

2003-present	Genetic Research Associate NMFS/JIMO Santa Cruz, CA
2002-2003	Ecologist/Research Manager Circuit Rider Productions Santa Rosa, CA
1995-2001	Staff Research Associate Bodega Marine Laboratory University of California, Davis Bodega Bay, CA

RESEARCH INTERESTS: Molecular population genetics, ecology, conservation biology, marine biology.

SELECTED PUBLICATIONS:

Hedgcock D., Banks M.A., Rashbrook V.K., Dean C.A., Blankenship S.M. 2001. Applications of population genetics to conservation of chinook salmon diversity in the Central Valley. In: Brown, RL, editor. Fish Bulletin 179: Contributions to the biology of Central Valley Salmonids. Sacramento (CA): California Department of Fish and Game.

Banks M.A., Rashbrook V.K., Calavetta M.J., Dean C.A., Hedgcock D. 2000 Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Canadian Journal of Fisheries and Aquatic Sciences 57: 915-927.

Grosholz E.D., Ruiz G.M., Dean C.A., Shirley K.A., Maron J.L., Connors P.G. 2000 The impacts of a nonindigenous marine predator in a California bay. Ecology 81: 1206-1224.

CURRICULUM VITAE

NAME: E. J. DICK

PRESENT POSITION: Fishery Biologist, Groundfish Analysis Team

EDUCATION: Ph.D. student, Dept. of Ocean Sciences, U.C. Santa Cruz ; B.S., Ecology and Evolution, U.C. Santa Cruz, 2002

PAST EXPERIENCE:

2002 - present	Fishery Biologist Groundfish Analysis Team NMFS / SWFSC Santa Cruz Laboratory
2002	Harvest Management Analyst Center for Stock Assessment Research University of California, Santa Cruz
2001	Biological Science Technician Habitat Ecology Team NMFS / SWFSC Santa Cruz Laboratory

RESEARCH INTERESTS: Stock assessment, generalized linear models, delta distributions.

PUBLICATIONS:

Ralston, S., and E.J. Dick. 2003. The status of black rockfish (*Sebastes melanops*) off Oregon and northern California in 2003. Pacific Fishery Management Council, Portland, Oregon.

He, X., S. Ralston, A. MacCall, D. Pearson, and E. Dick. 2003. Status of the widow rockfish resource in 2003. Pacific Fishery Management Council, Portland, Oregon.

Dick, E.J. In press. Beyond "lognormal vs. gamma": discrimination among error distributions for generalized linear models. Fisheries Research.

Benet, D.L, D.E. Pearson, and E.J. Dick. In prep. Fecundity, maturity and seasonal reproduction of female greenspotted rockfish, *Sebastes chlorostictus*.

CURRICULUM VITAE

NAME: CHRISTOPHER J. DONOHOE

PRESENT POSITION: Research Associate, Salmon Population Analysis Team

EDUCATION: Ph.D., Fisheries Science, Oregon State University, 2000; M.S., Biology and Ecology, San Diego State University, 1990; B.S., Marine Biology, Florida Institute of Technology, 1980.

PAST EXPERIENCE:

2002–present	Research Associate NOAA Fisheries, Southwest Fisheries Science Center c/o University of California, Santa Cruz Santa Cruz, California
1991–2000	Graduate Research Assistant / Teaching Assistant / Graduate Student Oregon State University, Department of Fisheries and Wildlife Corvallis, Oregon
1985–1991	Research Assistant San Diego State University, Department of Biology San Diego, California
1980–1982	Research Assistant Harbor Branch Oceanographic Institution Fort Pierce, Florida

RESEARCH INTERESTS: Relationships among life history forms in salmonids; early life history strategies of fishes; use of otolith microchemistry to reconstruct movements of fishes; fisheries oceanography and recruitment of coastal fishes; age and growth of fishes.

HONORS AND AWARDS: Research Assistance Award, American Institute of Fishery Research Biologists, 1996; Best Student Paper (runner up), American Society of Ichthyologists and Herpetologists, 1994.

SELECTED PUBLICATIONS:

Donohoe, C. J., and D. F. Markle. In prep. Metamorphosis and relationships to otolith microstructure and growth in Pacific sanddab, *Citharichthys sordidus* (Paralichthyidae).

Donohoe, C. J., and D. F. Markle. In prep. Settlement, distribution, and abundance of age-0 Pacific sanddab (*Citharichthys sordidus*) on the Oregon continental shelf.

Donohoe, C. J., and D. F. Markle. In prep. Ontogenetic and individual variation in otolith microchemistry of two recently-settled flatfishes, Dover sole (*Microstomus pacificus*) and Pacific sanddab (*Citharichthys sordidus*).

Donohoe, C. J., and D. F. Markle. In prep. Sources of variation in time series of otolith growth of settling Pacific sanddab, C*itharichthys sordidus* (Paralichthyidae).

Toole, C.L., D.F. Markle, and C.J. Donohoe. 1997. Settlement timing, distribution, and abundance of Dover sole (*Microstomus pacificus*) on an outer continental shelf nursery area. Canadian Journal of Fisheries and Aquatic Sciences. 54:531–542.

Donohoe, C.J. 1997. Age, growth, distribution, and food habits of recently settled white seabass, *Atractoscion nobilis*, off San Diego County, California. Fishery Bulletin. 95:709–721.

CURRICULUM VITAE

NAME: JOHN C. FIELD

PRESENT POSITION: Research Fishery Biologist, Groundfish Population Analysis Team

EDUCATION: B.A. Biology and Environmental Studies, University of California Santa Cruz, 1994; M.M.A. University of Washington, School of Marine Affairs, 1997; Ph.D. University of Washington, School of Aquatic and Fishery Sciences, 2004.

PAST EXPERIENCE:

2004 - present	Research Fishery Biologist National Marine Fisheries Service/SWFSC Santa Cruz Laboratory
2003-2004	Postdoctoral Research Fellow Institute of Marine Science/NMFS University of California, Santa Cruz
1999-2003	Research/Teaching Assistant School of Aquatic and Fishery Sciences University of Washington
1999-2000	Independent Contractor National Ocean Service/NOAA Silver Spring, MD
1998-1999	Knauss Sea Grant Fellow House Resources Committee Washington, D.C.

RESEARCH INTERESTS: Population dynamics and behavior, stock assessment and ecosystem modeling, ecosystem dynamics, fisheries oceanography, fisheries and ecosystem management, global climate change.

HONORS AND AWARDS: Claire L. and Evelyn S. Egtvedt Scholarship, University of Washington, 1999; W. Jones Award for Excellence in Coastal and Marine Graduate Study, 1997; Thesis honors, UC Santa Cruz, 1994.

SELECT SERVICE ON SCIENTIFIC COMMITTEES: National Center for Ecological Analysis and Synthesis Working Group Climate and Fisheries in North Pacific Ecosystems, 2001-present; Coastal and Marine Resources Team, U.S. National Assessment of the Potential Consequences of Climate Variability and Change, 1999-2001; U.S. Delegation to the International Commission for the Conservation of Atlantic Tunas, 1998.

SELECTED PUBLICATIONS:

Field, J.C. and S. Ralston. In prep. Spatial variability in California Current rockfish recruitment events.

Field, J.C. and R.C. Francis. 2002. Cooperating with the environment: Case studies of climate and fisheries in the Northern California Current. In N. McGinn (editor) Fisheries in a Changing Climate. American Fisheries Society Symposium 32: 245-260.

Scavia, D., J.C. Field, D.F. Boesch, R.W. Buddemeier, V. Burkett, D.R. Cayan, M. Fogarty, M.A. Harwell, R.W. Howarth, C. Mason, D.J. Reed, T.C. Royer, A.H. Sallenger, J.G. Tutus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25: 149-164.

Field, J.C., R.C. Francis, and A. Strom. 2001. Toward a fisheries ecosystem plan for the Northern California Current. California Cooperative Oceanic and Fisheries Investigations Reports 42: 74-87.

CURRICULUM VITAE

NAME: HEIDI E. FISH

PRESENT POSITION: Research Fishery Biologist, Salmon Population Analysis Team

EDUCATION: B.S., Zoology, California State University, Long Beach, 1983.

PAST EXPERIENCE:

1997–present	Research Fishery Biologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1996	Biological Science Technician NOAA Fisheries, Southwest Fisheries Science Center Tiburon, California
1990–1996	Fish and Wildlife Scientific Aide California Department of Fish and Game Long Beach and Menlo Park, California

RESEARCH INTERESTS: Salmon life history; stream survey methods.

HONORS AND AWARDS: Special Act Award, NOAA Fisheries, 2004 (two), 2003, 2001, 1998; Special Service Award, NOAA Fisheries, 2003, 2002, 2001; Certificate of Recognition, NOAA Fisheries, 1997.

PROFESSIONAL AFFILIATIONS: American Fisheries Society

SELECTED PUBLICATIONS:

Boughton, D. A., H. Fish, J. Goin, K. Pipal, F. Watson, J. Hagar, J. Casagrande, M. Stoecker. In prep. Contraction of the southern range limit for anadromous *Oncorhynchus mykiss*: migration-disruption and climate change hypotheses.

Garza, J. C., L. Gilbert-Horvath, J. Anderson, T. Williams, B. Spence, and H. Fish. 2004. Population structure and history of steelhead trout in California. Pages 129–131 *in* J. Irvine, et al., editors. Workshop on Application of Stock Identification in Defining Marine Distribution and Migration of Salmon. North Pacific Anadromous Fish Commission, Technical Report 5.

Adams, P. B., M. J. Bowers, H. E. Fish, T. E. Laidig and K. R. Silberberg. 1999. Historical and current presence-absence of coho salmon (*Oncorhynchus kisutch*) in the Central California Coast Evolutionarily Significant Unit. U.S. Department of Commerce, NOAA, NMFS, SWFSC, Administrative Report SC-99-02. 24 p.

Laidig, T. E., P. B. Adams, K. R. Silberberg and H. E. Fish. 1997. Conversions between total, fork and standard lengths for lingcod, *Ophiodon elongatus*. California Fish and Game 83(3):128–129.

CURRICULUM VITAE

NAME: REBECCA FISHER

PRESENT POSITION: Postdoctoral Research Associate

EDUCATION: Ph.D. Marine Biology, James Cook University (conferred Oct 2003); B.S. Honours (class 1), Marine Biology, James Cook University (1998).

PAST EXPERIENCE:

2003-present	Postdoctoral Research Associate NMFS/NOAA/SWFSC Santa Cruz, CA
1998-1999	Research Assistant James Cook University, Townsville, QLD Australia
1996	Research Assistant Adelaide University, Adelaide, SA Australia

RESEARCH INTERESTS: Biology and functional ecology of larval and juvenile fishes, population dynamics and recruitment variability of early life history stages, trade-offs in early life history strategies.

HONORS AND AWARDS: Lizard Island Doctoral Fellowship, Terry Walker Prize, CRC Reef Research Centre Merit Scholarship, Australian Postgraduate Award, Palmerston-Rundall Honours Prize, CRC Reef Research Centre Honours Prize, James Cook University Medal.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: CRC Reef Research Centre Augmentative Grant Research Committee (2002).

SELECTED PUBLICATIONS:

Fisher R (2004) Swimming speeds of larval coral reef fishes: impacts on self-recruitment and dispersal. Mar. Ecol. Prog. Ser. (in press)

Fisher R, Wilson SK (2004) Maximum sustainable swimming speeds of nine species of late stage larval reef fishes. J. Exp. Mar. Biol. Ecol. (in press)

Fisher R (2004) Nocturnal vertical distribution of late-stage larval coral reef fishes off the leeward side of Lizard Island, Great Barrier Reef, Australia. Bull. Mar. Sci. (in press)

Fisher R, Bellwood DR (2003) Swimming behaviour and nocturnal activity of coral reef fish larvae. Mar. Ecol. Prog. Ser. 263: 177-188

Fisher R, Bellwood DR (2002) Influence of swimming speed on sustained swimming performance of late stage reef fish larvae. Mar. Biol. 140: 801-807

Fisher R, Bellwood DR (2002) A light trap design for stratum specific sampling of reef fish larvae. J. Exp. Mar. Biol. Ecol. 269: 27-37

Fisher R, Bellwood DR (2001) Effects of feeding on the sustained swimming abilities of late stage *Amphiprion melanopus*. Coral Reefs 20: 151-154

Fisher R, Bellwood DR, Job S (2000) The development of swimming abilities in reef fish larvae. Mar. Ecol. Prog. Ser. 202: 163-173

CURRICULUM VITAE

NAME: ELLEN V. FREUND

PRESENT POSITION: Research Fishery Biologist, Salmon Ecology Team

EDUCATION: Ph.D., Biological Sciences, Stanford University, 1999; B.A., Biology, Brown University, 1989.

PAST EXPERIENCE:

2003- present	Research Fishery Biologist NMFS/SWFSC Santa Cruz, California
1999-2002	Post-doctoral Associate/ Preceptor Harvard University Cambridge, Massachusetts
1993-1999	Graduate Student Stanford University Stanford, California
1990-1992	Research Assistant Immulogic Pharmaceutical Corporation Palo Alto, California

RESEARCH INTERESTS: Physiological ecology, comparative zoology, functional morphology of vertebrates-specifically fish (teleosts and elasmobranchs).

HONORS AND AWARDS: Excellence in Teaching, Organismic and Evolutionary Biology Department, Harvard University, 2000 and 2001; Scholander Award, American Physiological Society, 2nd place 1999; National Science Foundation Predoctoral Fellowship, 1994; Magna Cum Laude and Honors, Brown University, 1989; Sigma Xi, Brown University, 1989.

SELECTED PUBLICATIONS:

Marcinek, D.J., S.B. Blackwell, H. Dewar, E.V. Freund, C. Farwell, D. Dau, A.C. Seitz, B.A. Block. 2001. Depth and muscle temperature of Pacific bluefin tuna examined with acoustic and pop-up satellite archival tags. Marine Biology, 138(4): 869-885.

Shiels, H.A., E.V. Freund, A.P. Farrell and B.A. Block, 1998. The sarcoplasmic reticulum plays a major role in isometric muscle contraction in atrial muscle from yellowfin tuna. Journal of Experimental Biology, 202: 881-890.

Block, B.A., J. Keen, B. Castillo, R. Brill, H. Dewar, E.V. Freund, D.J. Marcinek and C. Farwell, 1996. Environmental preferences of yellowfin tuna (*Thunnus albacares*) at the northern extent of its range. Marine Biology, 130: 119-132.

Brill, R.W., B.A. Block, C. Boggs, K. Bigelow, E.V. Freund and D.J. Marcinek, 1999. Horizontal and vertical movements of adult yellowfin tuna near the Hawaiian islands recorded using ultrasonic telemetry: Implications for the physiological ecology of pelagic fishes. Marine Biology, 133(3): 395-408.

Wasser, J.S., E.V. Freund, L.A. Gonzalez and D.C. Jackson, 1990, Force and acid-base state of turtle cardiac tissue exposed to combined anoxia and acidosis, American Journal of Physiology, 259(1 part 2): R15-R20.

Powell, T.J., J. Quan, E. Freund and W.C.A. Van Schooten, 1996, Activation of T cells by autoantigen immobilized by specific antibodies, Methods (Orlando), 9(3): 453-457.

Goldstein, L., S.R. Brill and E.V. Freund, 1990, Activation of taurine efflux in hypotonically stressed elasmobranch cells: Inhibition by stilbene disulfonates. Journal of Experimental Zoology, 254(1): 114-118.

CURRICULUM VITAE

NAME: JOHN CARLOS GARZA

PRESENT POSITION: Molecular Ecology Team Leader

EDUCATION: Ph.D. in Integrative Biology, 1998, University of California, Berkeley; M.S. in Biology, 1991, University of California, San Diego; B.A. (magna cum laude) in biology, 1990.

PAST EXPERIENCE:

2003-present	Supervisory Research Geneticist NOAA/NMFS/SWFSC Santa Cruz, CA
1999-2003	Research Geneticist NOAA/NMFS/SWFSC Santa Cruz, CA
1998-1999	Postdoctoral Fellow Museum of Vertebrate Zoology Berkeley, CA

RESEARCH INTERESTS: Population genetics, evolutionary ecology, molecular ecology of marine/anadromous fishes and marine mammals, inheritance of ecologically important traits.

HONORS AND AWARDS: NSF Postdoctoral Fellowship, 1998; NSF Dissertation Improvement Grant, 1996; UC San Diego Alumni Association-Scholar of the Year (Twice), 1990, 1989; Phi Beta Kappa, 1989.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: North-Central California Salmonid ESA Technical Recovery Team (2001-2004); Russian River Coho Recovery Work Group;Editorial Board, *Molecular Ecology*.

SELECTED PUBLICATIONS:

Garza JC; Anderson EC (submitted) Estimation of population size with molecular genetic data. *Molecular Ecology* submitted (invited review).

Pastor T, Garza JC, Allen P, Amos W, Aguilar A (2004). Low genetic variability in the highly endangered Mediterranean monk seal. *Journal of Heredity* 5: 291-300.

Wlasiuk G, Garza JC, Lessa EP (2003) Genetic and geographic differentiation in the Río Negro tuco-tuco (*Ctenomys rionegrensis*): inferring the roles of migration and drift from multiple genetic markers. *Evolution* 57: 913-926.

Garza JC, Williamson E (2001) Detection of reduction in population size using data from microsatellite DNA. *Molecular Ecology* 10: 305-318

Garza JC, Dallas J, Duryadi D, Gerasimov S, Croset H, Boursot P (1997) Social structure of the Mound-building mouse, *Mus spicilegus*, revealed by genetic analysis with microsatellites. *Molecular Ecology* 6: 1009-1017.

Garza JC, Freimer NB (1996) Homoplasy for size at microsatellite loci in humans and chimpanzees. *Genome Research* 6: 211-217.

Garza JC, Slatkin M, Freimer NB (1995) Microsatellite allele frequencies in humans and chimps with implications for constraints on allele size. *Molecular Biology and Evolution* 12: 594-603.

Di Rienzo A, Peterson AC, Garza JC, Valdes AM, Slatkin M, Freimer NB (1994) Mutational processes of simple-sequence repeat loci in human populations. *Proceedings of the National Academy of Sciences, USA* 91: 3166-3170.

Garza JC, Woodruff DS (1992) A phylogenetic study of the gibbons (*Hylobates*) using DNA obtained non-invasively from hair. *Molecular Phylogenetics and Evolution* 1: 202-210.

CURRICULUM VITAE

NAME: ELIZABETH ALICE GILBERT

PRESENT POSITION: Research Geneticist

EDUCATION: M.A. Biology, San Francisco State University, 2001; B.S. Zooloy, Oregon State University, 1989

EXPERIENCE:

2001 - present	Research Geneticist NOAA/NMFS Santa Cruz, California
2001	Marine Scientist Aquatic Farms Santa Cruz, California
2001	Research Technician San Francisco State University San Francisco, California
1998 - 2001	Graduate Assistant Conservation Genetics Laboratory San Francisco State University San Francisco, California

RESEARCH INTERESTS: Population genetics and phylogeography of marine and anadromous fishes, larval recruitment, molecular ecology

HONORS AND AWARDS: Myers Oceanographic and Marine Biology Trust research grant, 1998; Lerner-Gray Fund research grant, 1999; Sigma Xi research grant, 1999

SELECTED PUBLICATIONS and REPORTS:

Garza, John Carlos and Gilbert-Horvath, Elizabeth, 2003. Report on the genetics of coho salmon (*Oncorhynchus kisutch*) held at Warm Springs (Don Clausen) Hatchery for recovery efforts in the Russian River. NOAA/NMFS/SWFSC/Santa Cruz Lab Report, December 2003.

Gilbert, E.A., 2000. Molecular genetic analysis of temporal recruitment pulses in juvenile kelp rockfish. Master's Thesis, San Francisco State University, 75 pp.

CURRICULUM VITAE

NAME: CHURCHILL BRAGAW GRIMES

PRESENT POSITION: Director, Santa Cruz Laboratory

EDUCATION: B.S. and M.S. Biology, East Carolina University, Greenville, North Carolina, 1967, 1971; Ph.D., Marine Sciences, University of North Carolina, Chapel Hill, 1976.

PAST EXPERIENCE:

1993-1998	Laboratory Director
1984-1993	Fishery Ecologist National Marine Fisheries Service Panama City, Florida
1983-1984	Associate Professor of Marine Fisheries
1977-1983	Assistant Professor of Marine Fisheries Rutgers University New Brunswick, New Jersey

RESEARCH INTERESTS: Life history, population dynamics, fishery ecology, and recruitment dynamics.

HONORS AND AWARDS: Marine Science Fellowship, University of North Carolina, 1972-1973; Sigma XI; NMFS Outstanding Publication Award, *Fishery Bulletin*, Honorable Mention 1984; American Institute of Fishery Research Biologists: Associate 1975, Member 1980, Fellow 1990; American Fisheries Society: Florida Chapter, Outstanding Paper Award, February 1992 and 1993; Southern Division, Outstanding Achievement Award, 1996. NOAA Bronze Medal 1996; Monterey Bay National Marine Sanctuary, Current Symposium, Best Poster Award 2002.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: National Center for Ecological Analysis and Synthesis, Working Groups 2001 and 2003; NOAA Sea Grant Program Analysis Teams 2001 and 2003; Mexus Pacifico Working Group Chair 2000 – present; CNER Gulf Hypoxiz Working Group 1997-98; GMFMC Scientific and Statistical Committee 1997-98; ICES Recruitment Process Working Group 1994-98.

SELECTED PUBLICATIONS:

Grimes, C.B. and S. Ralston, 2003. Marine reserves: the best option for the oceans? Frontiers in Ecology and The Environment 1:496-497.

Yoklavich, M. M., C. B. Grimes, and W. W. Wakefield. 2003. Using laser line scan imaging technology to assess deepwater seafloor habitats in the Monterey Bay National Marine Sanctuary. Marine Technology Society Journal 37(1):18-26.

Sponangle, S., R.K. Cowan, A. Shanks, S.G. Morgan, J.M. Leis, J. Pineda , G. Boehlert, M.J. Kingsford, K. Lindeman, C.B. Grimes, and J.L. Munro. 2002. Predicting self-recruitment in marine populations: biophysical correlates and mechanisms. Bull. Mar. Sci. 70(1)supl.:341-375.

Allman, R.J. and C.B. Grimes. 2002. Temporal and spatial dynamics of spawning, settlement, and growth of gray snapper (*Lutjanus griseus*) from the West Florida shelf as determined from otolith microstructures. Fishery Bulletin 100(3):391-403.

DeVries, D.A., C.B. Grimes, and M.H. Prager. 2002. Using otolith shape analysis to distinguish eastern Gulf of Mexico and Atlantic Ocean stocks of king mackerel. Fish. Res. 57:51-62.

Levin, P.S. and C.B. Grimes. 2002. Reef fish ecology and grouper conservation and management. In: P. F. Sale (ed.), Coral reef fishes: dynamics and diversity in a complex ecosystem, p. 377-389. Academic Press**.**

Grimes, C.B. 2001. Fishery production and the Mississippi River discharge. Fisheries 26:17-26.

CURRICULUM VITAE

NAME: JEFFREY A. HARDING

PRESENT POSITION: Research Fishery Biologist, Salmon Ecology Team

EDUCATION: M.S., Zoology, Oregon State University. 1993; B.A., General Biology, University of California, San Diego. 1985

PAST EXPERIENCE:

2002 - present	Research Fishery Biologist NMFS/SWFSC Santa Cruz Laboratory, Santa Cruz, CA
2000 - 2001	Instructor (Biology, Marine Biology, Environmental Science) Monterey Peninsula College, Monterey, CA
1995 - 2002	Marine Biological Technician and Data Analyst University of California Santa Cruz and Santa Barbara, CA
1994	Instructor, Oregon Inst. Marine Biology (University Of Oregon Charleston, Oregon
1989 - 1993	Graduate Teaching Assistant and Graduate Research Assistant Oregon State University, Corvallis, OR

RESEARCH INTERESTS: Community ecology of coastal marine ecosystems, especially temperate rocky reefs, kelp forests, and coral reefs. Current research focus is growth, physiology, and trophic ecology of Pacific salmonids. In particular, my goals as a field biologist are to describe and evaluate the links between physical oceanographic conditions, coastal oceanic food webs, and juvenile salmon growth and survival in the bays, estuaries, and coastal ocean of central California.

HONORS AND AWARDS: Lerner-Gray Fund for Marine Research (1992); Sigma Xi Grants-in-Aid of Research (1992); OSU Zoology Research Fund (1991, 92, 93).

PUBLICATIONS:

Harding, J.A., Almany, G.R., Houck, L.D., and Hixon, M.A. 2003. Experimental analysis of monogamy in a Caribbean cleaner goby, *Gobiosoma evelynae*. Animal Behaviour, **65**, 865-874.

Carr, M.H., McGinnis, M.V., Forrester, G.E., Harding, J., and Raimondi, P.T. 2003. Consequences of alternative decommissioning options to reef fish assemblages and implications for decommissioning policy. MMS OCS Study 2003-053. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number 14-35-0001-30758. 104 pp.

CURRICULUM VITAE

NAME: SEAN A. HAYES

PRESENT POSITION: NRC Postdoctoral Fellow NOAA Fisheries, Santa Cruz

EDUCATION: Ph.D. Biology, 2002; MS. Biology, 1998 University of California Santa Cruz. B.S. Biology, 1994. Cornell University. A.S. Fisheries and Wildlife Technology, 1991, State University of New York, Cobleskill.

PAST EXPERIENCE:

2002 - 2003	Research Assistant I/III JIMO/NMFS Santa Cruz, CA
2001 -2001	Ecologist, GS 11 NMFS Honolulu, HI
1994-2001	Graduate Student University of California Santa Cruz Santa Cruz, CA

RESEARCH INTERESTS: Behavioral and physiological ecology of salmonids and pinnipeds

HONORS AND AWARDS: American Museum of Natural History Lerner-Gray Award 1997; American Museum of Natural History Theodore Roosevelt Award 1998; American Cetacean Society Research Award 2000; Animal Behavior Society Research Grant 2000; Earl & Ethel Myers Oceanographic and Marine Biology Award 1997, 1998, 2000; GAANN Graduate Fellowship 1995-1998, 2001; SigmaXi Award 1998.

SELECTED PUBLICATIONS:

Hayes, S. A., Bond, M. H., Hanson, C. V. & MacFarlane, R. B. (*In press*) Interactions between endangered wild and hatchery salmonids; can the pitfalls of artificial propagation be avoided in small coastal streams? *Journal of Fish Biology*.

Hayes, S. A., Costa, D. P., Harvey, J. T. & Le Boeuf, B. J. (2004) Aquatic mating strategies of the male Pacific harbor seal (Phoca vitulina richardsi); are males defending the hotspot? *Marine Mammal Science* **20**: 639-656.

Hayes, S. A., Costa, D. P., Harvey, J. T., Le Boeuf, B. J. & Garza, J. C. Evaluating the influence of the environment on reproductive success in an aquatic mating phocid. *In prep* for submission to Molecular Ecology.

Hayes, S. A., Kumar, A., Costa, D. P., Mellinger, D. K., Harvey, J. T., Southall, B. L. & Boeuf, B. J. L. (2004) Evaluating the function of male vocalizations in the harbor seal (*Phoca vitulina*) through playback experiments. *Animal Behaviour* **67**: 1133-1139.

Hayes, S. A., Mellinger, D. K., Costa, D. P., Croll, D. A. & Borsani, J. F. 2000. An inexpensive passive acoustic system for recording and localizing wild animal sounds. J. Acoust. Soc. Am., 107, 3552-3555.

CURRICULUM VITAE

NAME: XI HE

PRESENT POSITION: Fishery Biologist, Goundfish Analysis Team

EDUCATION: Ph.D., Oceanography and Limnology (minor: Biosystem Analysis), University of Wisconsin-Madion, 1990; M.S., Oceanography and Limnology, University of Wisconsin-Madison, 1986; B.S., Freshwater Aquaculture, Shanghai Fisheries University, China, 1982.

PAST EXPERIENCE:

1998 - 2002	Senior Research Scientist and Sub-program Leader CSIRO Marine Research Hobart, Australia
1996 – 1998	Aqautic Biologist Massachusetts Division of Marine Fisheries Gloucester , Massachusetts
1994 - 1996	Associate Researcher JIMAR, University of Hawaii Honolulu, Hawaii
1990 - 1994	Postdoctoral Researcher Center for Limnology, University of Wisconsin-Madison Madison, Wisconsin

RESEARCH INTERESTS: Population and ecosystem dynamics, food web analysis, fishing impacts on benthic habitat.

HONORS AND AWARDS: Lake Champlain Postdoctoral Award, University of Vermont, 1992.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Australian Fisheries Management Authority: South East Fishery Assessment Group, 1998-2002, Sub-Antarctic Fishery Assessment Group, 1999-2002. Atlantic States Fisheries Commission, Stock Assessment Subcommittee on Striped Bass, 1995-1996.

SELECTED PUBLICATIONS:

He, X, J.F. Kitchell and S. R. Carpenter. 1993. Food web configuration and long-term phosphorus recycling: A simulation model evaluation. Trans. Am. Fish. Soci. 112:773-783.

He, X. and G.W. LaBar. 1994. Interactive effects of cannibalism, recruitment, and predation on rainbow smelt in Lake Champlain: A modeling synthesis. J. Great Lakes Research, 20:289-298.

He, X. and G.H. Boggs. 1996. Estimating fisheries impacts using commercial fisheries data: Simulation models and time series analysis of Hawaii=s tuna fisheries. Proc. Second World Fisheries Congr. Australia, pp593-599.

Bigelow, K.A. C.H. Boggs, and X. He. 1999. Influence of environment factors on swordfish and blue shark catch rates in the US North Pacific longline fishery. Fishery Oceanography, 8:178-198.

Goldsworthy, S.D., X. He, M. Lewis, R. Williams and G. Tuck. 2001. Trophic interactions between Patagonian toothfish, its fishery, and seals and seabirds around Macquarie Island. Marine Ecology Progress Series, 218:283-302.

Bulman, C., X. He and A. Koslow. 2002. Trophic ecology of the mid-slope demersal fish community off southern Tasmania. J. Marine and Freshwater Research, 53:59-72.

He, X., F. M. Mangel, and A. MacCall. 2004 (submitted). A one-tailed prior for steepness based on an evolutionary persistence principle. Fishery Bulletin.

CURRICULUM VITAE

NAME: K KELLY HILDNER

PRESENT POSITION: Research Associate III

EDUCATION: Ph.D., Biology, University of California Santa Cruz, 2000; B.S., Ecology, Animal Behavior, and Evolution, University of California San Diego, 1991.

PAST EXPERIENCE:

2002 - present	Staff Research Associate III NMFS/ SWFSC Santa Cruz, California
2001 – 2002	Postgraduate Researcher University of California Santa Cruz Santa Cruz, CA
2001	Course Assistant, UCSC
1991 – 1999	Teaching Assistant, UCSC
1994 – 1995	Research Associate, UCSC
1993	Researcher/Writer The Conservation Fund Santa Cruz, CA

RESEARCH INTERESTS: Habitat restoration, conservation planning, habitat fragmentation, and genetic variability loss.

HONORS AND AWARDS: Elected - Sierra Club, Santa Cruz Group Executive Committee, 2003; Chair, Sierra Club, Santa Cruz Group Growth Management Committee, 2002-2003; GAANN fellowship, 1996-1998; Sigma Xi Grant-in-Aid of Research, Biology Department Summer Fellowship UC Santa Cruz, 1996; Sigma Xi Grant-in-Aid of Research, American Society of Mammalogists Grant-in-Aid of Research, 1995; Mathias Graduate Student Research Grant, 1994; Environmental Systems Research Institute course scholarships, 1992; Regent's fellowship UCSC, Summa Cum Laude UCSD, Muir Outstanding Scholar Award UCSD, Phi Beta Delta National Honor Society, 1991; John Muir College (UCSD) Caledonian Honor Society, 1990; Alumni Scholar UCSD, 1989

SELECTED PUBLICATIONS: Note: Some publications are under the name K. Kelly Moran

Hildner, K. K., and Soulé, M. E. 2004. Relationship between the energetic cost of burrowing and genetic variability among populations of the pocket gopher, *Thomomys bottae*: does physiological fitness correlate with genetic variability? J. Exper. Biol. 207(13): 2221-2227.

Hildner, K. K., Soulé, M. E., Min, M. S. , Foran, D. R. 2003. The relationship between genetic variability and growth rate among populations of the pocket gopher, *Thomomys bottae*. Conservation Genetics 4(2): 233-240.

Hildner, K.K. 2000. The Relationship Between Genetic Variability and Physiological Fitness Among Populations of the Pocket Gopher, *Thomomys bottae*, and its Implications for Conservation. Dissertation, University of California, Santa Cruz.

Doak, D. F., et al. [including K. Moran]. 1996. Natural Resources Management Plan: Naval Industrial Reserve Ordinance Plant, Santa Cruz.

Moran, K. K. 1994. Wildlife Corridors and Pipeline Corridors: A Comparative Analysis. Pp. 99-120 in K. G. Hay (ed.), Greenways, Wildlife and Natural Gas Pipeline Corridors: New Partnerships for Multiple Use.

Moran, K. K. 1994. Using Geographic Information Systems to Site Pipeline Corridors. Pp. 121-128 in K. G. Hay (ed.), Greenways, Wildlife and Natural Gas Pipeline Corridors: New Partnerships for Multiple Use.

CURRICULUM VITAE

NAME: JONGBUM KIM

PRESENT POSITION: Postdoctoral Researcher

EDUCATION: Ph.D., Systems Analysis and Economics, The Johns Hopkins University, 2003; M.S., Environmental Management, Carnegie Mellon University, 1997; B.S., Environmental Science, Yonsei University, Seoul, Korea, 1996.

PAST EXPERIENCE:

2003-Current	Postdoctoral Researcher NMFS/ SWFSC Santa Cruz, California
1997- 2003	Research Assistant The Johns Hopkins University, Maryland
1996- 1997	Research Assistant Carnegie Mellon University, Pittsburgh

RESEARCH INTERESTS: Risk-based decision analysis applied to environmental and natural resources management.

HONORS AND AWARDS: LG Global Challenger Grant, LG Co., Seoul, Korea, 1995; Scholarship for Outstanding Academic Performance, Yonsei University, Korea, 1994

SELECTED PUBLICATIONS:

Kim, J. B., B. F. Hobbs, and J. F. Koonce. 2003. Multicriteria Bayesian Analysis of Lower Trophic Level Uncertainties and Value of Research in Lake Erie, *Journal of Human and Ecological Risk Assessment*, vol. 9, pp. 1023-1057.

Kim, J.B. and B. F. Hobbs. In press. Response Surface Approximation in Bayesian Decision Analysis Using a Multidimensional Cubic Spline: Application to Lake Erie Ecosystem Management, *IEEE Transactions on Systems, Man, and Cybernetics, Part A*.

Kim, J.B. and B. F. Hobbs. In review. Effect of the Non-Linear Utility Function and Ecological Model on Lake Erie Ecosystem Management. *Decision Analysis*.

CURRICULUM VITAE

NAME: THOMAS E. LAIDIG

PRESENT POSITION: Research Fishery Biologist, Habitat Ecology Team

EDUCATION: M.A., Marine Biology, San Francisco State University, 1987; B.A., Aquatic Biology, University of California, Santa Barbara, 1983.

PAST EXPERIENCE:	1990-present	Research Fishery Biologist NMFS/SWFSC, Santa Cruz and Tiburon, California
	1989-1990	Biological Technician NMFS/SWFSC, Tiburon, California
	1988-1989	Biological Aid MFS/SWFSC, Tiburon, California

RESEARCH INTERESTS: Population dynamics, age and growth of fishes, salmonid life history and estuary residence times, video stock assessment, species identification, kelp bed ecosystems, and rockfish recruitment dynamics.

HONORS AND AWARDS: Certificates of Recognition, NMFS: Sustained Superior Performance Award, 1989, 1990, 1994.

SELECTED PUBLICATIONS:

Laidig, T. E., K. M. Sakuma, and J. A. Stannard. 2004. Description and growth of larval and pelagic juvenile pygmy rockfish (Sebastes wilsoni) (family Sebastidae). Fishery Bulletin 102(3):452-463.

Laidig, T. E., D. E. Pearson, and L. L. Sinclair. 2003. Age and growth of blue rockfish (Sebastes mystinus) from central and northern California. Fishery Bulletin 101(4):800-808.

Laidig, T. E. 2001. Continental slope communities. In: H. A. Karl, et al. (eds.), Beyond the Golden Gate: oceanography, geology, biology, and environmental issues in the Gulf of the Farallones (short general-audience version), p. 56-59. U.S. Geological Survey Circular 1198.

Laidig, T. E., K. R. Silberberg, and P. B. Adams. 2001. Age validation of the first, second, and third annulus from the dorsal fin rays of lingcod (Ophiodon elongatus). NOAA Technical Memorandum NMFS-SWFSC-306. 24 pp.

Laidig, T. 2001. Continental slope communities. In: H. A. Karl, et al. (eds.), Beyond the Golden Gate: oceanography, geology, biology, and environmental issues in the Gulf of the Farallones (full-length technical version), p. 185-191. U.S. Geological Survey Circular 1198.)

Silberberg, K. R., T. E. Laidig, P. B. Adams, and D. Albin. 2001. Analysis of maturity in lingcod, Ophiodon elongatus. California Fish and Game 87(4):139-152.

Laidig, Thomas E. 2001. Continental slope communities. In: H.A. Karl, et al. (eds.), Beyond the Golden Gate: oceanography, geology, biology and environmental issues in the Gulf of the Farallones (short general-audience version), p. 56-59. U.S. Geological Survey Circular 1198.

Laidig, Thomas E., Kelly R. Silberberg, and Peter B. Adams. 2001 Validation of the first, second, and third annulus from the dorsal fin rays of lingcod (*Ophiodon elongatus*). NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-306, 19 p.

Silberberg, Kelly R., Thomas E. Laidig, Peter B. Adams, and Douglas Albin. In press. Analysis of maturity in lingcod (*Ophiodon elongatus*). Cal. Fish Game.

Laidig, Thomas E., and Keith M. Sakuma. 1998. Description of pelagic larval and juvenile grass rockfish, *Sebastes rastrelliger* (Family Scorpaenidae), with an examination of age and growth. Fish. Bull. 96(4):788-796.

CURRICULUM VITAE

NAME: CHRISTOPHE LEMAIRE

PRESENT POSITION: Postdoctoral Research Associate

EDUCATION: PhD. in Biology, University of Paris, France 2001; B.A. (equivalent) in Biology, Université des Sciences et Technologies de Lille, France 1994.

PAST EXPERIENCE:

2004-present	Postdoctoral Research Associate Molecular Ecology Team NMFS/UCSC Santa Cruz, CA
2001-2003	Postdoctoral Researcher French Institute for Study and Explotation of the Sea (IFREMER) Laboratoire Biochimie des Protéines et Qualité Nantes, France

RESEARCH INTERESTS: Marine Fishes, population genetics, quantitative genetics, molecular evolution, phylogeny, statistical analyses, molecular biology, sampling techniques.

SELECTED PUBLICATIONS:

Lemaire C., Versini J-J., Bonhomme F. (in press) Maintenance of genetic differentiation across a transition zone in the sea : female biased reproductive isolation in the sea bass *Dicentrarchus labrax*. J. Evol. Biol.

Guinand B., Lemaire C., Bonhomme F. (in press) Genetic footprints of demography and adaptation: where are we with flat and other not so flatfish? J. Sea Research

Jerome M., Lemaire C., Bautista J. M., Fleurence J., Etienne M. 2003. Molecular phylogeny and species identification of Sardines. Journal of Agricultural and Food Chemistry 51: 43-50.

Jérôme M., Lemaire C., Verrez-Bagnis V., Etienne M. 2003. Direct sequencing method for species identification of canned sardines and sardine-type products. Journal of Agricultural and Food Chemistry 51: 7326 –7332.

Hassan, M., Lemaire, C., Fauvelot, C., Bonhomme F. 2002. 17 new EPIC-PCR amplifiable introns in fish. Mol. Ecol. Notes 2: 334.

Bahri-Sfar L., Lemaire C., Ben Hassine O.K., Bonhomme F. 2000. Fragmentation of sea bass populations in the western and eastern Mediterranean as revealed by microsatellite polymorphism. Proc. R. Soc. Lond. B 267: 929-935.

Lemaire C., Allegrucci G., Naciri M., Bahri-Sfar L., Kara H., Bonhomme F. 2000. Do discrepancies between microsatellite and allozyme variation reveal differential selection between sea and lagoon in the sea bass (*Dicentrarchus labrax*)? Mol. Ecol. 9: 457-67.

Naciri M., Lemaire C., Borsa P., Bonhomme F. 1999. Genetic study of the Atlantic/Mediterranean transition in sea bass (*Dicentrarchus labrax*). J. Hered 90: 591-596.

CURRICULUM VITAE

NAME: STEVEN T. LINDLEY

PRESENT POSITION: Ecologist, Salmon Population Analysis Team

EDUCATION: Ph.D., Biological Oceanography, Duke University, 1994; B.A. (with Honors and Distinction), Aquatic Biology, University of California, Santa Barbara, 1989.

PAST EXPERIENCE:

1996–present	Ecologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, CA
1995–1996	Research Associate Duke University Marine Laboratory Beaufort, NC
1994–1995	Postdoctoral Fellow Stanford University, Carnegie Institution of Washington Stanford, CA

RESEARCH INTERESTS: Population, community, and ecosystem ecology; numerical and statistical modeling; biological oceanography.

HONORS AND AWARDS: Bronze Medal, U.S. Department of Commerce, 2003.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Technical Recovery Team (Chair), California Central Valley salmonids, NOAA Fisheries, 2003–present; Biological Review Team, Green Sturgeon, NOAA Fisheries, 2002–present; Biological Review Team, West Coast salmonids, NOAA Fisheries, 1998–present.

SELECTED PUBLICATIONS:

Lindley, S. T., R. Schick, B. P. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. Population structure of threatened and endangered chinook salmon in California's Central Valley basin. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-SWFSC-370.

Lindley, S. T. 2003. Estimation of population growth and extinction parameters from noisy data. Ecological Applications 13:806–813.

Lindley, S. T. and M. S. Mohr. 2003. Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River winter-run chinook salmon (*Oncorhynchus tshawytscha*). Fishery Bulletin 101:321–331.

Lindley, S. T., M. S. Mohr and M. H. Prager. 2000. Monitoring protocol for Sacramento River winter chinook salmon: application of statistical power analysis to recovery of an endangered species. Fishery Bulletin 98:759–766.

Brodeur, R. D., G. W. Boehlert, E. Casillas, M. B. Eldridge, J. H. Helle, W. T. Peterson, W. R. Heard, S. Lindley and M. H. Schiewe. 2000. A coordinated research plan for estuarine and ocean research on Pacific salmon. Fisheries 25:7–16.

Chai, F., S. T. Lindley, J. R. Toggweiler, and R. T. Barber. 2000. Testing the importance of iron and grazing in the maintenance of the high nitrate condition in the equatorial Pacific Ocean: a physical-biological model study. Pages 155–186 *in* R. B. Hanson, H. W. Ducklow, and J. G. Field, editors. The Changing Ocean Carbon Cycle: a midterm synthesis of the Joint Global Ocean Flux Study. International Geosphere-Biosphere Programme Book Series 5. Cambridge University Press.

CURRICULUM VITAE

NAME: ALEC D. MacCALL

PRESENT POSITION: Supervisor, Groundfish Analysis Team

EDUCATION: Ph.D., Oceanography, Scripps Institution of Oceanography, University of California at San Diego, 1983; M.A., Biology, California State University at Long Beach, 1979; .B.A., Biology (with Distinction), University of Rochester, Rochester, New York 1969.

PAST EXPERIENCE:	1997 - present	Supervisor, Groundfish Analysis Team
	1988 - 1997	Director, NMFS/SWFSC/Tiburon Laboratory
	1982 - 1988	Fishery Biologist (Research) NMFS/SWFSC, La Jolla, California
	1974 - 1982	Marine Biologist (At separation - Senior Marine Biologist) California Department of Fish and Game c/o National Marine Fisheries Service La Jolla, California
	1986 - 1990	Adjunct Assistant Professor of Oceanography Scripps Institution of Oceanography, UCSD

RESEARCH INTERESTS: Population dynamics, ecology of fisheries, low frequency environmental variability, design of fishery management strategies.

HONORS AND AWARDS: California Department of Fish and Game Director=s Award, 1978; Research Fellowship, Sea Fisheries Research Institute, Department of Agriculture and Fisheries, Republic of South Africa, 1982; Washington Sea Grant Lecturer in Recruitment Oceanography, 1986.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Pacific Fishery Management Council: Northern Anchovy Plan Development Team, 1976-1988, Jack Mackerel Plan Development Team, 1978-1981, Scientific and Statistical Committee, 1988-1995, Groundfish Management Team, 1998-2002. California Sea Grant: California Sea Grant Committee, Member, 1988-1990. Pacific Seabird Group: Committee on Seabird-Fishery Interactions, Member, 1978-1985, Chairman, 1986-1991.

SELECTED PUBLICATIONS:

Stephens, A., and A. D. MacCall. In press. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fisheries Research.

MacCall, A. D. 2003. Status of bocaccio off California in 2003. PFMC, Portland OR.

MacCall, A. D., and T. C. Wainwright (eds). 2003. Assessing extinction risk for West Coast salmon: Proceeding of the workshop (November 13-15, 1996, Seattle, Washington). NOAA Tech. Mem. NMFS-NWFSC-56. 197 p.

MacCall, A. D. 2002. Fishery management and stock rebuilding prospects under conditions of low frequency environmental variability and species interactions. Bull. Mar. Sci. 70:613-628.

MacCall, A. D. 2002. An hypothesis explaining biological regimes in sardine-producing Pacific boundary current systems (South America, North America, and Japan): implications of alternating modes of slow, meandering flow and fast linear flow in the offshore region. In: A. Bakun and K. Broad (eds.), Climate and fisheries: interacting paradigms, scales, and policy approaches: the IRI-IPRC Pacific Climate-Fisheries Workshop (Honolulu, 14-17 November 2001). International Research Institute for Climate Prediction, Columbia University, Palisades, NY.

MacCall, Alec D. 2002. Use of known-biomass production models to determine productivity of west coast groundfish stocks. N. Am. J. Fish. Mgmt. 22:272-279.

MacCall, Alec D., and Stephen Ralston. 2002. Is logarithmic transformation <u>really</u> the best procedure for estimating stock-recruitment relationships? N. Am. J. Fish. Mgmt. 22:339-350.

CURRICULUM VITAE

NAME: R. BRUCE MacFARLANE

PRESENT POSITION: Salmon Ecology Team Leader

EDUCATION: Ph. D., Oceanography, Florida State University, 1980; M.S., Oceanography, Florida State University, 1970; B.S., Zoology, Pennsylvania State University, 1968.

PAST EXPERIENCE:

1980-present	Research Fishery Biologist NMFS/SWFSC Santa Cruz and Tiburon, California
1978-1980	Instructor, Department of Oceanography Florida State University Tallahassee, Florida

RESEARCH INTERESTS: Salmon biology, physiological ecology, biochemistry of fishes, pollutant dynamics, biological/chemical oceanography.

HONORS AND AWARDS: NOAA Bronze Medal, 2003; Best Publication in Fishery Bulletin, 2002; National Research Council Post-doctoral Fellow Advisor, 1998-present; Outstanding Performance Award, NOAA/NMFS/SWFSC, 1984, 1990, 1994-5, 1997, 1999-2000; Quality Step Increase, NOAA/NMFS/SWFSC, 1990, 1998; Sustained Superior Performance Award, 1985, 1986; Commendation for Technical Advice, Aquatic Habitat Program, Resolution #85-16, San Francisco Bay Regional Water, Quality Control Board, Oakland, California, 1985; Society of Sigma Xi Doctoral Assistance Grant.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Scientific Advisory Committee, California Coastal Ocean Currents Monitoring Program, 2004; Technical Advisory Committee, Comparative Lagoon Ecological Assessment Project, County of Santa Cruz, CA, 2004; Central Valley Technical Recovery Team; California Ocean Observation System (Prop 40) Scientific Advisory Panel; San Francisco Estuary Project, Technical Advisory Committee, U.S. EPA, Region IX, San Francisco; CALFED Technical Advisory Group; NMFS/CDFG Anadromous Fish Hatchery Review Committee.

SELECTED PUBLICATIONS:

MacFarlane, R.B., S. Ralston, C. Royer, and E.C. Norton. In press. Juvenile chinook salmon (Oncorhynchus tshawytscha) growth on the central California coast during the 1998 El NiZo and 1999 La NiZa. Fisheries Oceanography

Eldridge, M. B., E. C. Norton, B. M. Jarvis, and R. B. MacFarlane. 2002. Energetics of early development in the vivaparous yellowtail rockfish. Journal of Fish Biology 61:1122-1134.

MacFarlane, R. B., S. Ralston, C. Royer, and E. C. Norton. 2002. Influences of the 1997- 1998 El Niño and 1999 La Niña on juvenile chinook salmon in the Gulf of the Farallones. PICES Scientific Report No. 20:25-29.

MacFarlane, R.B. and E.C. Norton. 2002. Physiological ecology of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and the Gulf of the Farallones, California. Fishery Bulletin. 100:244-257.

Norton, E.C., R.B. MacFarlane, and M.S. Mohr. 2001. Lipid class dynamics during development in early life stages of shortbelly rockfish and their application to condition assessment. Journal of Fish Biology 58:1010-1024.

MacFarlane, R.B. and E.C. Norton. 1999. Nutritional dynamics during embryonic development in the viviparous genus *Sebastes* their application to the assessment of reproductive success. Fishery Bulletin, U.S. 97:273-281.

MacFarlane, R.B. and M.J. Bowers. 1995. Matrotrophic viviparity in the yellowtail rockfish *Sebastes flavidus*. J. exp. Biol. 198:1197-1206.

CURRICULUM VITAE

NAME: MICHAEL S. MOHR

PRESENT POSITION: Mathematical Statistician and Leader, Salmon Population Analysis Team

EDUCATION: Graduate study, Biostatistics, University of California, Berkeley; M.S., Fisheries, Humboldt State University, 1986; B.A., Mathematics, Humboldt State University, 1983; B.S., Fisheries, Humboldt State University, 1980.

PAST EXPERIENCE:

1996–present	Mathematical Statistician NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1994–1995	Statistical Consultant California Department of Fish and Game Office of Oil Spill Prevention and Response Sacramento, California
1994	Visiting Assistant Professor Humboldt State University, Departments of Mathematics and Fisheries Arcata, California

RESEARCH INTERESTS: Estimator development; population dynamics; stock assessment; fishery management under uncertainty.

HONORS AND AWARDS: Special Service Award, NOAA Fisheries, 2003, 2001; Bronze Medal, U.S. Department of Commerce, 2002; Outstanding Performance Award, NOAA Fisheries, 2002, 1999; Employee of the Year, NOAA Fisheries, 2001; Special Act, NOAA Fisheries, 2001, 1999 (two); High Level of Performance, NOAA Fisheries, 1997.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Fishery Management Plan Amendment Group, Central Valley Chinook, Pacific Fishery Management Council, 2002–present; Salmon Technical Team, Pacific Fishery Management Council, 1997–present; Klamath River Technical Advisory Team, Klamath Fishery Management Council, 1997–present; Biological Review Team, coho salmon, NOAA Fisheries, 1996–1997; Mass Mark Working Group, NOAA Fisheries, 1996–1997.

SELECTED PUBLICATIONS:

Lindley, S. T., and M. S. Mohr. 2003. Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River winter-run chinook salmon (*Oncorhynchus twhawytscha*). Fishery Bulletin 101:321–331.

Grover, A. M., M. S. Mohr, and M. L. Palmer-Zwahlen. 2002. Hook-and-release mortality of chinook salmon from drift mooching with circle hooks: management implications for California's ocean sport fishery. Pages 39–56 *in* J. A. Lucy and A. L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries Society, Symposium 30, Bethesda, Maryland.

Prager, M. H., and M. S. Mohr. 2001. The harvest rate model for Klamath River fall chinook salmon, with management applications and comments on model development and documentation. North American Journal of Fisheries Management 21:533–547.

Norton, E. C., R. B. MacFarlane, and M. S. Mohr. 2001. Lipid class dynamics during development in early life stages of shortbelly rockfish and their application to condition assessment. Journal of Fish Biology 58:1010–1024.

Lindley, S. T., M. S. Mohr, and M. H. Prager. 2000. Monitoring protocol for Sacramento River winter chinook salmon, *Oncorhynchus tshawytscha*: application of statistical power analysis to recovery of an endangered species. Fishery Bulletin 98:759–766.

CURRICULUM VITAE

NAME: ELIZABETH C. NORTON

PRESENT POSITION: Research Fishery Biologist, Salmon Ecology Team

EDUCATION: B.A., Aquatic Biology, University of California, Santa Barbara

PAST EXPERIENCE:

1990-present	Research Fishery Biologist, NMFS Santa Cruz and Tiburon, California
1987-1990	Biological Technician, NMFS Tiburon, California
1985-1987	Educational Sales Representative, Portland, Oregon
1984-1985	Foreign Fisheries Observer in Alaska, NMFS, Seattle, Washington

RESEARCH INTERESTS: Salmon feeding ecology, zooplankton ecology, fish nutritional status.

HONORS AND AWARDS: NOAA Performance Awards 1993, 1994, 1995, 1996, 2000, 2001, 2002, 2003; NOAA Fisheries Best Scientific Publication Award, Fishery Bulletin 2002; Alpha Computers Sales Award; University of California Chancellor's Scholar.

SELECTED SERVICE ON COMMITTEES: SWR EEO Advisory Committee, Chair of the Personnel Subcommittee, 2000-2002; NMFS, SWFSC, Tiburon Laboratory EEO Committee, 1989-1991;

SELECTED PUBLICATIONS:

MacFarlane, R. B., S. Ralston, C. Royer and E. C. Norton. In review. Effect of El Nino on growth of juvenile chinook salmon in the coastal waters of California. Fisheries Oceanography.

Eldridge, M. B., E. C. Norton*, B. M. Jarvis and R. B. MacFarlane. 2002. Energetics of early development in the viviparous yellowtail rockfish. J. of Fish Biol. 61:1122-1134.

MacFarlane, R. B. and E. C. Norton. 2002. Physiological ecology of juvenile chinook salmon (*Onchorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and Gulf of the Farallones, California. Fish. Bull. U.S. 100:244-257.

Norton, E. C., R. B. MacFarlane and M. S. Mohr. 2001. Lipid class dynamics during development in early life stages of shortbelly rockfish (*Sebastes jordani*) and their application to condition assessment. J. Fish Biol. 58, 1010-1024.

Norton, E. C. and R. B. MacFarlane. 1999. Lipid class composition of the viviparous yellowtail rockfish (*Sebastes flavidus*) over the reproductive cycle. J. Fish Biol. 54:1287-1299.

MacFarlane, R. B. and E. C. Norton. 1999. Nutritional dynamics during embryonic development in the viviparous genus *Sebastes* and their application to the assessment of reproductive success. Fish. Bull., U.S. 97:273-281.

MacFarlane, R. B. and E. C. Norton. 1996. Lipid and protein changes during embryo development in the viviparous genus *Sebastes*: Application to the assessment of reproductive success. *In* Don MacKinlay and Maxwell Eldridge (eds.), The fish egg: Its biology and culture, p. 95-102. Intl. Congress on the Biology of Fishes, AFS, Phys. Section.

Norton, E. C. and R. B. MacFarlane. 1995. Nutritional dynamics of reproduction in viviparous yellowtail rockfish (*Sebastes flavidus*). Fish. Bull. U. S. 93:299-307.

CURRICULUM VITAE

NAME: DEVON E PEARSE

PRESENT POSITION: Research Molecular Geneticist

EDUCATION: University of Georgia, Dept. of Genetics, Ph.D., 2001, Population Genetics. University of California, Santa Cruz, BA, 1996, Biology.

PAST EXPERIENCE:

2003-present	Research Molecular Geneticist NMFS/NOAA/SWFSC Santa Cruz, CA
2001-2003	Post-Doctoral Researcher Brigham Young University Provo, UT

RESEARCH INTERESTS: Population and conservation genetics, behavioral ecology and mating systems of turtles, Salmonids, Rockfish.

HONORS AND AWARDS: David M. Kennedy Center for International Studies, Brigham Young University, 2003; Linnaeus Fund Research Award, Chelonian Research Foundation, 2002-'03; University of Georgia Doctoral Dissertation Completion Fellowship, 2000-'01; NIH training grant, Dept. of Genetics, UGA, 1997-'98; '98-'99; '99-2000; Senior Thesis Honors, Department of Biology, UC Santa Cruz, 1996; Robert M. Norris Undergraduate Research Fund, UC Natural Reserve System, 1996.

SELECTED PUBLICATIONS:

Pearse, D. E. & Crandall, K. A. Beyond Fst: Analysis of population genetic data for conservation. *In press*.

Pearse, D. E., Janzen, F. J., & Avise, J. C. 2002. Multiple paternity, sperm storage, and reproductive success of female and male painted turtles (*Chrysemys picta*) in nature. *Behavioral Ecology and Sociobiology*. 51:164-171.

Avise, J.C, Jones, A. G., Walker D., DeWoody, J. A., and collaborators (Pearse, D. E, one of 7 other authors). 2002. Genetic mating systems and reproductive natural histories of fishes: lessons for ecology and evolution. *Annual Review of Genetics*. 36:19-45.

Pearse, D. E., Eckerman, C. M., Janzen, F. J., & Avise, J. C. 2001. A genetic analogue of 'Mark-Recapture' methods for estimating population size: An approach based on molecular parentage assessments. *Molecular Ecology*. 10:2711-2718.

Pearse. D. E. & Avise, J. C. 2001. Turtle mating systems: behavior, sperm storage, and genetic paternity. *Journal of Heredity* v92, pp. 206-211.

Pearse, D. E., Janzen, F. J., & Avise, J. C. 2001. Genetic markers reveal long-term storage and utilization of sperm by female painted turtles. *Heredity* 86(3), pp. 378-384.

Pearse, D. E. & Pogson, G. 2000. Phylogeography of the California legless lizard, *Anniella pulchra*: Evidence for parallel evolution of the melanistic morph. *Evolution* 54(4), pp. 1041-1046.

Goodisman, M. A. D., Mack, P. D., Pearse, D. E., & Ross, K. G. 1999. Effects of a single gene on worker and male mass in the Fire Ant *Solenopsis invicta* (Hymenoptera: Formicidae). *Ann. Entomological Soc. America* 92(4), pp. 563-570.

Ortí, G., D. E. Pearse, & Avise, J. C. 1997. Phylogenetic assessment of length variation at a microsatellite locus. *Proc. Natl. Acad. Sci.* USA, v.94, pp. 10745-10749.

CURRICULUM VITAE

NAME: DONALD E. PEARSON

PRESENT POSITION: Fishery Biologist, Groundfish Population Analysis Team

EDUCATION: M.S., Biology, University of the Pacific, 1985; B.S., Ecology, San Jose State University, 1980.

PAST EXPERIENCE:

1987-present	Fishery Biologist, Fishery Technician NMFS/ SWFSC Santa Cruz and Tiburon Laboratories
1986-1987	Biological Technician California Department of Fish and Game Menlo Park, California
1983-1985	Graduate Assistant University of the Pacific Stockton, California

RESEARCH INTERESTS: Stock assessment, population ecology, age and growth, and fisheries dependent research.

HONORS AND AWARDS: NOAA Certificates of Recognition, 1993, 1994; NOAA Sustained Outstanding Performance Award, 1990, 2001; Honorable Mention Best Publication, Fisheries Bulletin, 1989; NOAA Special Achievement Award, 1987, 2003.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Groundfish Management Team member, 1991-1993; Applications Target Architecture Team member, 1997-1998, NMFS coordinator for California Cooperative Survey, 1986-present.

SELECTED PUBLICATIONS:

Pearson, Donald E., and F.R. Shaw. 2004. Sources of age determination errors for sablefish (Anoplopoma fimbria). Fish. Bull., U.S. 102:127-141.

Pearson, Donald E. 2000. Data availability, landings, and length trends of California=s rockfish. U.S. Dept. Comm. Admin. Rpt. SC-00-01. 94pp.

Pearson, Donald E. 1996. Timing of hyaline-zone formation as related to sex, location, and year of capture in otoliths of the widow rockfish Sebastes entomelas. Fish. Bull., U.S. 94:190-197.

Pearson, Donald E. 1994. An initial examination of the status of the bank rockfish fishery off the coast of California. Appendix E. In Status of the Pacific Coast Groundfish Fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Portland, Oregon.

Pearson, Donald E., David A. Douglas, and Bill Barss. 1993. Biological observations from the Cobb Seamount rockfish fishery. Fish. Bull., U. S. 91(3):573-576.

Pearson, Donald E., and Joseph E. Hightower. 1991. Spatial and temporal variability in growth of widow rockfish (Sebastes entomelas). U. S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-167, 43 p.

Pearson, Donald E., Joseph E. Hightower and Jacqueline T. H. Chan. 1991. Age, growth, and potential yield for shortbelly rockfish Sebastes jordani. Fish. Bull., U. S. 89(3):403-409.

CURRICULUM VITAE

NAME: KERRIE A. PIPAL

PRESENT POSITION: Laboratory Assistant III (Research Fishery Biologist)

EDUCATION: M.S., Natural Resources Management, Fisheries Biology, Humboldt State University, Arcata, CA, 2003; B.S., Biological Sciences, Marine Biology, California Polytechnic State University, San Luis Obispo, CA, 1993.

PAST EXPERIENCE:

2002 - Present	Research Fishery Biologist/Laboratory Assistant NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1998 - 2001	Senior Clinical Data Coordinator Quintiles Pacific, Inc. Mountain View, California
1995 - 1997	Naturalist and Lead Kayaking Guide Seaquest Expeditions and Zoetic Research Friday Harbor, San Juan Island, Washington
1994 - 1995	Nature Discovery Center Intern The Conservancy, Inc. Naples, Florida
1993 - 1994	Marine Biology Instructor Catalina Island Marine Institute Two Harbors, Catalina Island, California

RESEARCH INTERESTS: Salmon and steelhead ecology and life history; field survey methodology; data analysis.

HONORS AND AWARDS: Humboldt State University, Arcata, CA, Marin Rod and Gun Club Scholarship Award.

PROFESSIONAL AFFILIATIONS: American Fisheries Society

CURRICULUM VITAE

NAME: STEPHEN VAN DYKE RALSTON

PRESENT POSITION: Research Fishery Biologist, Groundfish Population Analysis Team

EDUCATION: Ph.D., Fisheries, University of Washington, Seattle, 1981; M.S., Zoology, University of Hawaii, Honolulu, 1975; B.A., Zoology, University of California, Los Angeles, 1971.

PAST EXPERIENCE:	1988-present	Research Fisheries Biologist NMFS/SWFSC Santa Cruz and Tiburon California
	1986-1988	Task Leader, Insular Stock-Assessment NMFS/SWFSC Honolulu, Hawaii
	1978-1982	Fishery Biologist Fisheries Research Institute, University of Washington Seattle, Washington

RESEARCH INTERESTS: Fisheries population dynamics, stock assessment, age and growth of fishes, recruitment processes, fishery oceanography.

HONORS AND AWARDS: Honolulu Laboratory Nominee for Manager of the Year, 1986; NMFS Publications Advisory Committee Honorable Mention for best publication in U.S. Fishery Bulletin, 1984, 1985, 1986.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Scientific and Statistical Committee, Pacific Fishery Management Council, 1999-present; Groundfish Management Team, Pacific Fishery Management Council, 1995-1997; External Examiner, University of North Queensland, Australia, 1995; Master's Thesis Committee, U.S. Naval Postgraduate School, Monterey, California, 1998; Master's Thesis Committees, California State University, San Francisco, 1991, 1992, 1996, 1998-present; Master's and Doctoral Thesis Committees, University of Hawaii, Honolulu, 1984-1986, 1989; Bottomfish/Seamount Plan Development and Monitoring Teams, Western Pacific Fishery Management Council, 1979-1988.

SELECTED PUBLICATIONS:

MacFarlane, R. B., S. Ralston, C. Royer, and E. C. Norton. In press. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) growth on the central California coast during the 1998 El Niño and 1999 La Niña. Fish. Oceanogr.

Starr, R. M., V. O'Connell, and S. Ralston. In press. Movements of lingcod (Ophiodon elongatus) in southeast Alaska: potential for increased conservation and yield from marine reserves. Can. J. Fish. Aquat. Sci. 61:1-13.

Dalton, M. G., and S. Ralston. 2004. The California rockfish conservation area and groundfish trawlers at Moss Landing Harbor. Mar. Res. Econ. 19(1):67-83.

Brodeur, R. D., W. G. Pearcy, and S. Ralston. 2003. Abundance and distribution patterns of nekton and micronekton in the Northern California Current Transition Zone. J. Oceanogr. 59: 515-535.

Ralston, S., J. R. Bence, M. B. Eldridge, and W. H. Lenarz. 2003. An approach to estimating rockfish biomass based on larval production, with application to Sebastes jordani. Fish. Bull. 101:129-146.

Ralston, S., and E. J. Dick. 2003. The status of black rockfish (*Sebastes melanops*) off Oregon and northern California in 2003. In: Status of the Pacific Coast Groundfish Fishery Through 2003, Stock Assessment and Fishery Evaluation, Volume 1. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, Oregon, 97220-1384.

Ralston, S. 2002. The west coast groundfish harvest policy workshop. N. Amer. J. Fish. Management. 22:249-250.

CURRICULUM VITAE

NAME: DAVID E. RUNDIO

PRESENT POSITION: Research Fishery Biologist, Salmon Population Analysis Team

EDUCATION: M.S., Fisheries Science, Oregon State University, 2002; B.S., Biology, Utah State University, 1996.

PAST EXPERIENCE:

2003–present	Research Fishery Biologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1997–2003	Biological Science Technician USDA Forest Service, Pacific Northwest Research Station Corvallis, Oregon
1996	Biological Science Technician (Fisheries) USDA Forest Service Thorne Bay, Alaska
1994–1996	Research Assistant Utah State University, Department of Fisheries and Wildlife Logan, Utah

RESEARCH INTERESTS: Freshwater ecology of salmonids; aquatic-terrestrial food web linkages; stream ecology; behavioral ecology; fish-habitat relationships.

HONORS AND AWARDS: Savery Outstanding Master's Student Award, Oregon State University, 2002; Thomas G. Scott Grant Scholarship, Oregon State University, 2002; Certificate of Merit, USDA Forest Service, 2000, 1999, 1998, 1996.

SELECTED PUBLICATIONS:

Rundio, D. E., and D. H. Olson. 2003. Antipredator defenses of larval Pacific giant salamanders (*Dicamptodon tenebrosus*) against cutthroat trout (*Oncorhynchus clarki*). Copeia 2003:392-397.

Rundio, D. E., and D. H. Olson. 2001. Palatability of southern torrent salamander (*Rhyacotriton variegatus*) larvae to Pacific giant salamander (*Dicamptodon tenebrosus*) larvae. Journal of Herpetology 35:133-136.

CURRICULUM VITAE

NAME: KEITH M. SAKUMA

PRESENT POSITION: Research Fishery Biologist, Groundfish Population Analysis Team

EDUCATION: M.A., Marine Biology, San Francisco State University, 1992; B.A., Zoology, University of Hawaii, Manoa, 1987.

PAST EXPERIENCE:

1992-present	Research Fishery Biologist NMFS/SWFSC Santa Cruz and Tiburon, California
1991-1992	Student Trainee in Biological Sciences NMFS/SWFSC Tiburon, California
1989-1992	Teaching Assistant/Graduate Assistant San Francisco State University San Francisco, California
1985-1989	Fishery Aide State of Hawaii Division of Aquatic Resources Honolulu, Hawaii

RESEARCH INTERESTS: Fisheries oceanography, age and growth of larval and juvenile fish, larval fish taxonomy, and population dynamics.

SELECTED PUBLICATIONS:

Sakuma, K.M., F.B. Schwing, M.H. Pickett, D.A. Roberts, and S. Ralston. 2002. The physical oceanography off the central California coast during May-June, 2000: a summary of CTD data from pelagic juvenile rockfish surveys. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-318, 83 pp.

Sakuma, K.M., S. Ralston, and D.A. Roberts. 1999. Diel vertical distribution of post-flexion larval *Citharichthys* spp. and *Sebastes* spp. off central California. Fisheries Oceanogr. 8:68-76.

Sakuma, K.M., S. Ralston, W.H. Lenarz, and M. Embury. 1999. Effects of the parasitic copepod *Cardiodectes Medusaeus* on the lanternfishes *Diaphus theta* and *Tarletonbeania crenularis* off central California. Environ. Biol. Fishes 55:423-430.

Sakuma, K.M., and S. Ralston. 1997. Vertical and horizontal distribution of juvenile Pacific whiting (*Merluccius productus)* in relation to hydrography off California. Calif. Coop. Oceanic Fish. Invest. Rep. 38:137-146.

Sakuma, Keith M., and Thomas E. Laidig. 1995. Description of larval and pelagic juvenile chilipepper, *Sebastes goodei* (family Scorpaenidae), with an examination of larval growth. Fish. Bull. 93:721-731.

Sakuma, Keith M., and Stephen Ralston. 1995. Distributional patterns of late larval groundfish off central California in relation to hydrographic features during 1992 and 1993. Calif. Coop. Oceanic Fish. Invest. Rep. 36:179-192.

Sakuma, Keith M., and Ralph J. Larson. 1995. Distribution of pelagic metamorphic-stage sanddabs *Citharichthys sordidus* and *C. stigmaeus* within areas of upwelling off central California. Fish. Bull. 93:516-529.

CURRICULUM VITAE

NAME: ROBERT S. SCHICK

PRESENT POSITION: Ecologist, Salmon Population Analysis Team

EDUCATION: M.E.M., Resource Ecology, Duke University, 2002; B.S., Zoology, University of Washington, 1997.

PAST EXPERIENCE:

2002–present	Ecologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
2000–2002	Assistant Scientist (GIS) New England Aquarium, Edgerton Research Lab Boston, Massachusetts

RESEARCH INTERESTS: Spatial dynamics of species in relation to environmental variables; quantifying empirical relationships between marine species and measurable oceanographic variables; application of GIS & remote sensing to ecological research; connectivity of threatened populations; numerical ecology and landscape ecology.

HONORS AND AWARDS: Environmental Internship Fund Fellow, Duke University, 1999; Merit Scholarship, Nicholas School of the Environment, Duke University, 1998; Dean's list, University of Washington, 1996–1997, 1992–1993.

SELECTED PUBLICATIONS:

Schick, R. S., A. L. Edsall, and S. T. Lindley. 2004. Historical and current distribution of Pacific salmonids in the Central Valley, California. U.S. Department of Commerce, NOAA, NMFS, SWFSC, Administrative Report SC-2004-01. 30 p.

Lindley, S. T., R. S. Schick, B. P. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. Population structure of threatened and endangered chinook salmon in California's Central Valley basin. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-370. 67 p.

Schick, R. S., J. Goldstein, and M. E. Lutcavage. 2004. Bluefin tuna (*Thunnus thynnus*) distribution in relation to sea surface temperature fronts in the Gulf of Maine (1993–1996). Fisheries Oceanography 13(4):225–238.

Schick, R. S. 2002. Spatial Correlation between bluefin tuna and sea surface temperature fronts. *In* J. Breman, editor. Marine Geography. ESRI Press, Redlands, CA.

Schick, R. S. 2002. Using GIS to Track Right Whales and Bluefin Tuna in the Atlantic Ocean. *In* D. J. Wright, editor. Undersea with GIS. ESRI Press, Redlands, CA.

Schick, R. S. 2001. Tuna distribution in relation to physical features in the Gulf of Maine. *In* C. Convis, editor. Conservation Geography: Case Studies in GIS, Computer Mapping, and Activism. ESRI Press, Redlands, CA.

Schick, R. S. and D. L. Urban. 2000. Spatial components of bowhead whale (*Balaena mysticetus*) distribution in the Alaskan Beaufort Sea. Canadian Journal of Fisheries and Aquatic Sciences 57:2193–2200.

CURRICULUM VITAE

NAME: SUSAN M. SOGARD

PRESENT POSITION: Ecology Branch Chief

EDUCATION: Ph.D. in ecology, October 1990, Rutgers University, New Brunswick, New Jersey; M.S. in marine biology, July 1982, University of Miami, Miami, Florida; B.S. (cum laude) in zoology and psychology, May 1977.

PAST EXPERIENCE:

2001-present	Supervisory Research Fishery Biologist NMFS/NOAA/SWFSC Santa Cruz, CA
1993-2001	Oceanographer NMFS/NOAA/AFSC Newport, OR
1984-1987	Research Biologist National Audubon Society Tavernier, FL

RESEARCH INTERESTS: Behavioral and population ecology of marine organisms, population dynamics and recruitment variability of early life history stages, costs of growth in juvenile fishes, life history strategies.

HONORS AND AWARDS: NOAA Special Service Award, 1999, 2000, 2002, 2003; Stoye Award, best student paper, ASIH meeting, 1990; J. Frances Allen Scholarship, American Fisheries Society, 1990.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Science Advisory Group of the Interagency Ecological Program on San Francisco Bay fisheries research (1999-2004); Higher Trophic Level Initiative, Florida Bay Research Program (1997); National Undersea Research Program Panel (1996); National Sea Grant Fisheries Panel (1993); EPA Global Climate Change Program (1992).

SELECTED PUBLICATIONS:

Hurst, T.P., M.L. Spencer, S.M. Sogard, and A.W. Stoner. In press. Compensatory growth, energy storage and behavior of juvenile Pacific halibut *Hippoglossus stenolepis* following a thermally induced growth reduction. Mar. Ecol. Prog. Ser.

Berkeley, S.A., C. Chapman, and S.M. Sogard (2004). Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. Ecology 85:1258-1264.

Sogard, S.M. and M.L. Spencer. 2004. Energy allocation in juvenile sablefish: effects of temperature, ration and body size. J. Fish Biol. 64:726-738.

Duffy-Anderson, J., L. Ciannelli, T. Honkalehto, K.M. Bailey, S.M. Sogard, A.M. Springer, and T. Buckley (2003). Distribution of age-1 and age-2 walleye pollock in the Gulf of Alaska and eastern Bering Sea: sources of variation and implications for higher trophic levels. In: The Big Fish Bang: Proceedings of the 26th Annual Larval Fish Conference, H.I. Browman and A.B. Skiftesvik (eds).

Sogard, S.M. and B.L. Olla. 2002. Contrasts in the capacity and underlying mechanisms for compensatory growth in two pelagic marine fishes. Mar. Ecol. Prog. Ser. 243:165-177.

Sogard, S.M. and B.L. Olla. 2001. Growth and behavioral responses to elevated temperatures by juvenile sablefish (*Anoplopoma fimbria*) and the interactive role of food availability. Mar. Ecol. Prog. Ser. 217: 121-134.

Sogard, S.M., K.W. Able and S.M. Hagan. 2001. Long-term assessment of settlement and growth of juvenile winter flounder (*Pseudopleuronectes americanus*) in New Jersey estuaries. J. Sea Res. 45:189-204.

CURRICULUM VITAE

NAME: BRIAN C. SPENCE

PRESENT POSITION: Research Fishery Biologist, Salmon Population Analysis Team

EDUCATION: Ph.D., Fisheries Science, Oregon State University, 1995; M.S., Natural Resources (Fishery Science), Cornell University, 1989; B.S., Wildlife and Fisheries Biology, University of California, Davis, 1983.

PAST EXPERIENCE:

2000–present	Research Fishery Biologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1998–2000	Visiting Faculty The Evergreen State College, Environmental Studies Olympia, Washington
1996–1997	Aquatic Ecologist Umpqua Land Exchange Project Corvallis, Oregon
1995–1996	Fisheries Project Scientist ManTech Environmental Research Services Corporation Corvallis, Oregon

RESEARCH INTERESTS: Life-history variation in Pacific salmonids; salmonid habitat relationships; effects of human perturbations on aquatic ecosystems; conservation biology of resident and anadromous fishes.

HONORS AND AWARDS: Bronze Medal, U.S. Department of Commerce, 2003; Best Student Paper, American Fisheries Society (Oregon Chapter), 1994; Outstanding Teaching Assistant, Cornell University (Department of Natural Resources), 1987.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Biological Review Team, West Coast salmonids, NOAA Fisheries, 2003–present; Technical Recovery Team, North-Central California Coast salmonids, NOAA Fisheries, 2001–present.

SELECTED PUBLICATIONS:

Spence, B. C., and E. P. Bjorkstedt. In press. Central California Coast coho salmon. Pages C54–C70 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.

Spence, B. C., T. C. Wainwright, and E. P. Bjorkstedt. In press. Southern Oregon/Northern California Coasts coho salmon. Pages C30–C53 *in* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum.

Hobbs, S. H., R. L. Beschta, E. D. Clark, W. Dennison, J. Gabriel, S. Garman, R. Gill, S. Gregory, R. Jones, W. McComb, A. McKee, K. Pollett, W. Ripple, J. Sessions, B. C. Spence, D. Vesely, and D. Wagner. 1998. Pilot study report: Umpqua Land Exchange Project. World Forestry Center, Portland, OR. 170 p. + appendices.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corporation, Corvallis, OR. 356 p.

Spence, B. C. 1995. Geographic variation in timing of fry emergence and smolt migration in coho salmon (*Oncorhynchus kisutch*). Ph.D. thesis, Oregon State University, Corvallis, OR. 201 p.

Gucinski, H., R. T. Lackey, and B. C. Spence. 1991. Global climate change: Policy implications for fisheries. Fisheries 15(6):33–38.

CURRICULUM VITAE

NAME: ERICK A. STURM

PRESENT POSITION: Research Fishery Biologist

EDUCATION: M.A., Biology, California State University, Fullerton, 1997; B.S., Biological Sciences, University of Southern California, 1991.

PAST EXPERIENCE:

2002 - present	Research Fishery Biologist NMFS, Southwest Fisheries Science Center Santa Cruz, California
1999 - 2002	Research Fishery Biologist NMFS, Alaska Fisheries Science Center Newport, Oregon
1997 - 1999	Biological Technician Kindred Communications, Inc. Hatfield Marine Science Center Newport, Oregon

RESEARCH INTERESTS: Fish nutrition in captive situations, design of saltwater and freshwater aquarium systems for long term holding of fishes in experimental research situations, and improving husbandry techniques for fishes kept in experimental research facilities. Biological and environmental factors effecting the growth and maturation of coho salmon in captive broodstock programs. Diet and digestive abilities of marine herbivorous fishes, biogeography of fishes and how this changes with warm water and El Niño events.

HONORS AND AWARDS: Merit Award, F/AKC, NMFS, 1999

SELECTED PUBLICATIONS:

Stoner, A.W. and E.A. Sturm. 2004. Temperature and hunger mediate sablefish (*Anoplopoma fimbria*) feeding motivation: implications for stock assessment. Canadian Journal of Fisheries and Aquatic Sciences 61: 238-246.

Ryer, C.H., M.L. Ottmar, and E.A. Sturm. 2004. Behavioral impairment after escape from trawl codends may not be limited to fragile species. Fisheries Research 66 (2-3):261-269.

Sturm, E.A. and M.H. Horn. 2001. Increase in occurrence and abundance of zebraperch *(Hermosilla azurea)* in the Southern California Bight in recent decades. Bulletin of the Southern California Academy of Science.

Sturm, E.A. and M.H. Horn. 1998. Food habits, gut morphology and pH, and assimilation efficiency of the Zebraperch (*Hermosilla azurea*), an herbivorous kyphosid fish of temperate marine waters. Marine Biology, 132:515-522.

Sturm, E.A. 1997. Food habits, gut morphology and pH, and assimilation efficiency of the Zebraperch (*Hermosilla azurea*, Jenkins and Evermann), an herbivorous kyphosid fish of temperate marine waters. Master of Arts Thesis. California State University, Fullerton. 37 p.

Sturm, E.A. and M.H. Horn. 1996. Diet and digestive efficiency of zebraperch, *Hermosilla azurea,* an herbivorous fish of southern California marine waters. pp. 41-44. In: Gutshop '96: Feeding Ecology and Nutrition in Fish Symposium Proceedings. International Congress of the Biology of Fishes. San Francisco State University. (Non peer reviewed publication.)

CURRICULUM VITAE

NAME: R. GLENN SZERLONG

PRESENT POSITION: Research Associate, Salmon Population Analysis Team

EDUCATION: M.S., Statistics, University of Idaho, 2003; B.S., Fisheries Biology, Colorado State University, 1996.

PAST EXPERIENCE:

2002–present	Research Associate NOAA Fisheries, Southwest Fisheries Science Center c/o University of California, Santa Cruz Santa Cruz, California
1999–2001	Graduate Research Assistant University of Idaho, Department of Statistics Moscow, Idaho
1999–2001	Statistical Consultant Nez Perce Tribe, Fisheries Research Branch Lapwai, Idaho
1998–1999	Fisheries Biologist Nez Perce Tribe, Fisheries Research Branch Enterprise, Oregon
1996–1998	Fisheries Technician Columbia River Inter-Tribal Fisheries Commission Portland, Oregon

RESEARCH INTERESTS: Population dynamics; time-series analysis; stochastic processes; statistical ecology; mark-recapture modeling; abundance estimation.

HONORS AND AWARDS: Dale Hein Award for Student Excellence, Colorado State University, 1996.

SELECTED PUBLICATIONS:

Szerlong, R. G. 2003. Time-series analysis of Chinook salmon redd counts: Accommodating density dependence and environmental conditions in estimates of annual recruitment. M.S. Thesis. University of Idaho, Moscow, Idaho.

Dennis, B. and G. Szerlong. 1999. Population viability analyses of Snake River spring/summer Chinook spawning populations. Idaho Department of Fish and Game, Progress report, Boise, Idaho.

Fryer, J. K. and R. G. Szerlong. 1997. Age and length composition of Columbia Basin Chinook and sockeye salmon at Bonneville Dam. Columbia River Inter-Tribal Fish Commission, Progress report, Portland, Oregon.

Fryer, J. K. and R. G. Szerlong. 1997. Identification of Columbia Basin sockeye salmon stocks using scale-pattern analyses. Columbia River Inter-Tribal Fish Commission, Progress report, Portland, Oregon.

Johnson, B. M., M. J. Wise, C. J. Counard, and R. G. Szerlong. 1995. Ecological effects of reservoir operations on Blue Mesa Reservoir. U.S. Bureau of Reclamation, Progress report, Grand Junction, Colorado.

CURRICULUM VITAE

NAME: CYNTHIA J. THOMSON

PRESENT POSITION: Economics Team Leader, Fisheries Branch

EDUCATION: B.A., 1972; M.A. Economics, 1977; University of California, San Diego.

PAST EXPERIENCE:

1996-present	Economics Team Leader NMFS/SWFSC Santa Cruz, California
1978-1996	Economist NMFS/SWFSC La Jolla, California
1975-1977	Teaching Assistant, Department of Economics University of California, San Diego La Jolla, California

RESEARCH INTERESTS: Fishery management, non-market valuation, economics of habitat restoration, marine protected areas.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Pacific Fishery Management Council, Scientific and Statistical Committee, 1991-present (Chair 2000-2001; Chair, SSC Marine Reserve Subcommittee, 2001-present); RecFIN Committee, 1996-present; State of California Squid Research Scientific Committee, 1999-2001; NOAA Superfund Litigation Team, 1993-1996; PFMC Coastal Pelagics Plan Development Team, 1991-1994; PFMC Anchovy Plan Development Team, 1989-1991.

SELECTED PUBLICATIONS:

Thomson, C. 2004. Conclusions and Recommendations. In: Allen, S.T., C.Thomson and R. Carlson (eds.). *Proceedings of the Salmon Habitat Restoration Cost Workshop*. Pacific States Marine Fisheries Commission, Portland, OR.

Allen, S.T., C.Thomson and R. Carlson (eds.). 2004. *Proceedings of the Salmon Habitat Restoration Cost Workshop*. Pacific States Marine Fisheries Commission, Portland, OR.

Thomson, C.J. 2001. The human ecosystem. In: Leet, W. et al. (eds.). *California's Living Marine Resources: A Status Report.* California Department of Fish and Game.

Thomson, C.J. et al. 2000. *Overcapitalization in the West Coast Groundfish Fishery: Background, Issues and Solutions*. Prepared for the Pacific Fishery Management Council by the Scientific and Statistical Committee, Economics Subcommittee. 116 p.

Thomson, C.J. 1999. Economic and implications of no-take reserves: an application to *sebastes* rockfish in California. *Calif. Coop. Oceanic Fish. Invest. Rep*. 40:107-117.

Thomson, C. 1998. Evaluating marine harvest refugia: an economic perspective. In: Yoklavich, Mary (ed.). *Marine Harvest Refugia for West Coast Rockfish: A Workshop*. U.S. Dep. Commer., NOAA Tech Memo, NOAA-TM-NMFS-SWFSC-255.

Thomson, C. 1997. Analysis of agency costs attributable to the Recovery Plan for Sacramento River winter-run chinook salmon. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-249.

Kling, C.L. and C.J. Thomson. 1996. The implications of model specification for welfare estimation in nested logit models. *American Journal of Agricultural Economics.* 78:103-114.

CURRICULUM VITAE

NAME: DAVID TOMBERLIN

PRESENT POSITION: Economist, Fisheries Branch

EDUCATION: Ph.D., Forest Economics, University of Wisconsin - Madison, 1999; M.S., Agricultural and Resource Economics, North Carolina State University, 1993; B.A., English and Creative Writing, Princeton University, 1988.

PAST EXPERIENCE:

1999-present	Economist NMFS/ SWFSC Santa Cruz, California
1993-1999	Research Assistant Department of Forestry, University of Wisconsin
1998	Economics Consultant Food and Agriculture Organization, Rome, Italy
1992-1993	Research Assistant North Carolina State University, Raleigh, North Carolina
1988-1990	Lecturer Universitas Bung Hatta, Padang, Indonesia

RESEARCH INTERESTS: Resource management under uncertainty, real options analysis in public policy, commercial fishing fleet dynamics, fish/forestry interactions, watershed management

HONORS AND AWARDS: McGovern Scholar, 1997, 1998; USDA National Research Initiative grantee, 1994, 1998, 2003; Center for Southeast Asian Studies Fellow, 1995; Magna Cum Laude, Phi Beta Kappa, Croll Prize, 1988

SELECTED PUBLICATIONS:

Holloway, G., D. Tomberlin, and X. Irz. In press. Hierarchical Analysis of Production Efficiency in a Coastal Trawl Fishery. In A. Alberini and R. Scarpa, eds., *Applications of Simulation Methods in Environmental and Resource Economics*. Boston: Kluwer Academic Press.

Ish, T., and D. Tomberlin. In press. Simulation of Surface Erosion on a Logging Road in the Jackson Demonstration State Forest. In *Proceedings of the 2004 Redwood Region Forest Science Symposium*. Berkeley, CA: University of California Center for Forestry.

O'Hanley, J., and D. Tomberlin. In press. Optimizing the Removal of Small Artificial Fish Passage Barriers. *Environmental Modeling and Assessment*.

Tomberlin, D. and V. Bosetti. In press. Solving Real Options Models of Fisheries Investment When Salvage Value Is Difficult to Estimate. In *Proceedings of the 2004 IIFET Convention*. Corvallis, OR: International Institute for Fisheries Economics and Trade.

Bosetti, V., and D. Tomberlin. 2004. Real Options Analysis of Fishing Fleet Dynamics: A Test. FEEM Natural Resource Management Working Paper 102. Milan: Fondazione Eni Enrico Mattei.

Tomberlin, D. 2004. The allocation problem in habitat restoration. In S.T. Allen, C. Thomson and R. Carlson, eds., *Proceedings of the Salmon Habitat Restoration Cost Workshop*. Gladstone, OR: Pacific States Marine Fisheries Commission.

Buongiorno, J., S. Zhu, D. Zhang, J. Turner, and D. Tomberlin. 2003. *The Global Forest Products Model: Structure, Estimation, and Applications*. New York: Academic Press.

CURRICULUM VITAE

NAME: BRIAN K. WELLS

PRESENT POSITION: Postdoctoral Research Fellow

EDUCATION: Ph. D., Ecology, Old Dominion University, 2000; M.S., Biology, Old Dominion University, 1994; B.S., Fisheries and Wildlife, Virginia Tech, 1991.

PAST EXPERIENCE:

2002-present	Adj. Assist. Prof., Dept. of Natural Resources and Conservation University of Massachusetts Amherst Amherst, MA
2002-2003	National Research Council Associate, NMFS Woods Hole Woods Hole, MA
2000-2002	Fishery Biologist (GS-482-11), USFWS Annapolis, MD

RESEARCH INTERESTS: Population ecology, fisheries dynamics, population connectivity.

HONORS AND AWARDS: Best Publication in Transactions of the American Fisheries Society, 2003; National Research Council Postdoctoral Fellow, 2002-2003, Virginia Sea Grant.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: For ASMFC I served on Striped Bass Technical Committee, Weakfish Technical Committee, Striped Bass Tagging Committee, Striped Bass Assessment Committee.

SELECTED PUBLICATIONS:

Wells, B.K., C.B. Grimes, J.C. Field, C.S. Reiss. *In review*. Covariation between the average lengths of mature coho (*Oncorhynchus kisutch*) and Chinook salmon (*Oncorhynchus tshawytscha*) and the ocean environment. *Fisheries Oceanography*.

Wells, B.K., K.D. Friedland, L. M. Clarke. 2003. Increment patterns in otoliths and scales from mature Atlantic salmon *Salmo salar*. *Marine Ecology Progress Series*. 262:293-298.

Wells, B. K., S. R. Thorrold, and C. M. Jones. 2003. Stability of elemental signatures in the scales of spawning weakfish, *Cynoscion regalis. Canadian Journal of Fisheries and Aquatic Sciences*. 60:361-369.

Wells, B. K., B. E. Rieman, J. L., J. L. Clayton, D. Horan, and C. M. Jones. 2003. Relationships between water, otolith, and scale chemistries of westslope cutthroat trout from the Coeur d'Alene River, Idaho: the potential application of hard-part chemistry to describe movements in fresh water. *Transactions of the American Fisheries Society.* 132:409-424.

Wells, B. K. and C. M. Jones. 2002. Reproduction of black drum, *Pogonias cromis,* in the Chesapeake Bay region. *Virginia Journal of Science.* 33:3-11.

Jones, C. M. and B. K. Wells. 2001. Yield-per-recruit analysis for black drum, *Pogonias cromis*, along the East Coast of the U.S. and management strategies for the Chesapeake Bay. *Fishery Bulletin*. 99:328-337.

Wells, B. K., G. E. Bath, S. R. Thorrold, and C. M. Jones. 2000. Incorporation of strontium, cadmium, and barium in juvenile spot (*Leiostomus xanthurus*) scales reflects water chemistry. *Canadian Journal of Fisheries and Aquatic Sciences*. 57: 2122-2129.

Wells, B. K., S. R. Thorrold, and C. M. Jones. 2000. Geographic variation in elemental signatures of weakfish scales. *Transactions of the American Fisheries Society*. 129: 889-900.

Jones, C. M. and B. Wells. 1998. Age, growth, and mortality of black drum. *Pogonias cromis*, in the Chesapeake Bay. *Fishery Bulletin* 96: 451 – 461.

CURRICULUM VITAE

NAME: THOMAS H. WILLIAMS

PRESENT POSITION: Research Fishery Biologist, Salmon Population Analysis Team

EDUCATION: Ph.D., Fisheries Science, Oregon State University, 2004; M.S., Fish and Wildlife Management, Montana State University, Bozeman, 1990; B.S., Fisheries, Humboldt State University, 1985.

PAST EXPERIENCE:

1998–present	Research Fishery Biologist NOAA Fisheries, Southwest Fisheries Science Center Santa Cruz, California
1992–1998	Graduate Research/Teaching Assistant Oregon State University, Department of Fisheries and Wildlife Corvallis, Oregon
1991–1992	Research Assistant Oregon State University, Oregon Cooperative Wildlife Research Unit Corvallis, Oregon

RESEARCH INTERESTS: Ecology of Pacific salmonids and relations among marine, freshwater, and terrestrial communities; conservation biology and conservation genetics related to conservation of Pacific salmon and trout.

PROFESSIONAL AFFILIATIONS: American Fisheries Society; Gilbert Ichthyological Society.

HONORS AND AWARDS: Outstanding Performance Award, NOAA Fisheries, 1999; Best Student Paper, American Fisheries Society (Oregon Chapter), 1997; Robert Marriott Scholarship, Federation of Fly Fishers, 1996; Lee Wulff Memorial Scholarship, Trout Unlimited, 1993.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: Technical Recovery Team (Co-chair), Oregon and Northern California Coasts, NOAA Fisheries, 2002–present; Technical Recovery Team Workgroup (Chair), Southern Oregon/Northern California, NOAA Fisheries, 2001–present; Biological Review Team, West Coast salmonids, 2001, 1998; Technical Panel, Workshop on Assessing Extinction Risk for West Coast Salmonids, NOAA Fisheries, 1996; Recovery Team (staff), Northern Spotted Owl, U.S. Fish and Wildlife Service, 1991–1992.

SELECTED PUBLICATIONS:

Williams, T. H., and G. H. Reeves. 2003. Ecological diversity and extinction risk of Pacific salmon and trout. Pages 107–115 *in* T. Wainwright and A. MacCall, editors. Assessing extinction risk for West Coast. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-56.

Spence, B. C., T. H. Williams, E. P. Bjorkstedt, and P. B. Adams. 2001. Status review update for coho salmon (*Oncorhynchus kisutch*) from the Central California Coast and the California portion of the Southern Oregon/Northern California Coasts Evolutionarily Significant Units. NOAA Fisheries, Santa Cruz, CA.

Williams, T. H., and G. H. Reeves. 2001. Identification and conservation considerations of hybrids between coastal cutthroat trout and steelhead trout. Pages 259–260 *in* M. K. Brewin, A. J. Paul, and M. Monita, editors. Bull trout II conference proceedings. Trout Unlimited Canada, Calgary, Alberta.

Williams, T. H., K. P. Currens, N. E. Ward III, and G. H. Reeves. 1997. Genetic population structure of coastal cutthroat trout. Pages 16-17 *in* J. D. Hall, P. A. Bisson, and R. G. Gresswell, editors. Sea-run cutthroat trout: biology, management, and future conservation. American Fisheries Society, Oregon Chapter, Corvallis, OR.

Allendorf, F. W., D. Bayles, D. L. Bottom, K. P. Currens, C. A. Frissell, D. Hankin, J. A. Lichatowich, W. Nehlsen, P. C. Trotter, and T. H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. Conservation Biology 11:140–152.

CURRICULUM VITAE

NAME: LISA M. WOONINCK

PRESENT POSITION: Research Fishery Biologist, Habitat Ecology Team

EDUCATION: Ph.D., Ecology, Evolution & Marine Biology, University of California, Santa Barbara, 2003**;** M.S. with distinction, Biology, California State University, Northridge, 1993**;** B.A., Biology with an emphasis in Aquatic Biology, California State University, Northridge, 1990.

PAST EXPERIENCE:	2001 - present	Research Fishery Biologist, NMFS Santa Cruz, California
	2000 – 2001	National Knauss Sea Grant Fellow Staff member of Congressman Farr Washington, DC

RESEARCH INTERESTS: Marine protected areas, reproductive ecology of fishes, population dynamics and recruitment processes.

HONORS AND AWARDS: National Sea Grant Knauss Fellowship, 2000; Smithsonian Predoctoral Fellowship, 1997; Raney Fund, American Society of Ichthyology and Herpetology, 1997; President=s Year Fellowship, University of California, 1996; Smithsonian Graduate Student Fellowship, 1995; First Prize, Student Research Presentation, Sigma XI, CSUN, 1992

SELECTED PUBLICATIONS:

Wooninck, L.M. and C. Bertrand. 2004. Marine managed areas designated by NOAA Fisheries: a characterization study and preliminary assessment. In *Aquatic Protective Areas as Fisheries Management Tool.* J.B. Shipley, ed. American Fisheries Society, Alpharetta, GA.

Wooninck, L.M., R.R. Warner, and R.C. Fleischer. 2000. Relative fitness components measured with competitive PCR. Molecular Ecology, 9, 1409-1414.

Wooninck, L.M., R.C. Fleischer, and R.R. Warner. 1998. Characterization of microsatellite loci in a pelagic spawner: the bluehead wrasse, *Thalassoma bifasciatum*. Molecular Ecology, 7, 1613-1614.

Wooninck, L.M. and R.R. Warner. (in Prep). Paternity and mechanisms of individual fertilization success in mixed-male phenotype matings of a coral reef fish.

Wooninck, L.M. and R.R. Warner (In Prep). Paternity in group spawns of a coral reef fish.

CURRICULUM VITAE

NAME: MARY M. YOKLAVICH

PRESENT POSITION: Research Fishery Biologist, Habitat Ecology Team

EDUCATION: M.S., Marine Sciences, Moss Landing Marine Labs, San Francisco State University, 1982; B.A., Biological Sciences, University of California, Santa Barbara, 1973.

PAST EXPERIENCE:

1988-present	Research Fishery Biologist NOAA Fisheries Alaska Fisheries Science Center, Seattle (1988-89) Pacific Fisheries Environmental Laboratory, Pacific Grove (1991-99) SWFSC, Santa Cruz, California (1999-present)
1989-1991	Research Associate Moss Landing Marine Labs and Elkhorn Slough Foundation Moss Landing, California
1984-1988	Senior Research Assistant, Oregon State University College of Oceanic and Atmospheric Sciences Newport, Oregon

RESEARCH INTERESTS: Species - habitat associations, developing new technologies to assess groundfishes and habitats, marine protected areas, larval and juvenile fish ecology.

HONORS AND AWARDS: National Outdoor Book Award, Nature Guidebook Category, 2003; NOAA Fisheries Employee of the Year Award,2002; Special Service Achievement Award, 2002; Fellow, AIFRB, 2002; Distinguished Fellow in Science and Technology, California State University, Monterey Bay, 2000; Bronze Medal - Superior Federal Service, U.S. DOC, 1998; Nominee for Pew Fellows Program in Marine Conservation, 1998; NOAA Monterey Bay National Marine Sanctuary Science Award, 1998; NOAA Performance Awards, 1988, 1992-98.

SELECTED SERVICE ON SCIENTIFIC COMMITTEES: National Center for Ecological Analysis and Synthesis "Practical Design of Marine Reserves" Working Group 2002; Advisor on NMFS EIS for Groundfish EFH, 2002-present; California Marine Life Protection Act Master Plan Team, 2000-2004; PFMC, Advisory Committee on Marine Reserves, 1999-2001; NOAA-NMFS P/R Panel for Candidate Species, 1997-2002; NOAA-NMFS EFH Core Team, 1996-1999.

SELECTED PUBLICATIONS:

Yoklavich, M., C. Grimes, and W.W. Wakefield. (2003). Using laser line scan imaging technology to assess deepwater seafloor habitats in the Monterey Bay National Marine Sanctuary. Marine Technology Society Journal 37:18-26.

Yoklavich, M., G. Cailliet, D. Oxman, J.P. Barry, and D.C. Lindquist. (2002). Fishes. In Caffrey, J., M. Brown, W.B. Tyler, and M. Silberstein (Eds.). Changes in a California Estuary: a Profile of Elkhorn Slough. 163-185 p.

Yoklavich, M., G. Cailliet, R.N. Lea, H.G. Green, R. Starr, J. deMarignac, and J. Field. (2002). Deepwater habitat and fish resources associated with the Big Creek Ecological Reserve. CalCOFI Reports 43: 120-140.

Love, M.S., M. Yoklavich and L. Thorsteinson. (2002) The Rockfishes of the Northeast Pacific. University of California Press, 405 p.

Yoklavich, M., H. G. Greene, G. Cailliet, D. Sullivan, R. Lea, and M. Love. (2000). Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fishery Bulletin, U.S. 98:625-641.

Yoklavich, M. (Ed.) (1998). Marine harvest refugia for west coast rockfish: A workshop. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-255. 159 p.(also now available online at www.pfeg.noaa.gov).

APPENDIX B

PUBLICATIONS OF THE SANTA CRUZ LABORATORY

2002 - 2004

CURRENT MANUSCRIPTS

Adams, P. B., W. M. Samiere, and C. J. Ryan.
In prep. Diet and prey switching of a marine predator, chinook salmon (*Oncorhynchus tshawytscha*) and their management implications.

Agrawal, A., **R. G. Szerlong**, and **E. Bjorkstedt**.
In prep. An evaluation of interpolation methods for increasing DEM resolution with application to estimating fine-scale stream gradient.

Allen, L. G., **M. Yoklavich**, and G. Cailliet.
In review. Bay and estuarine fishes. In: L. Allen, M. Horn, and D. Pondella (eds.), Ecology of California marine fishes. University of California Press.

Alonzo, J. J., and **R. B. MacFarlane**.
In prep. Smoltification in chinook salmon (*Oncorhynchus tshawytscha*) from California's central valley.

Amend, M., **M. Yoklavich**, Y. Rhzanov, **C. Grimes**, and W. Wakefield.
In prep. Mosaics of benthic habitats using laser line scan technology: it's in the details.

Anderson, E. C.
In prep. A review of statistical methods for identifying hybrids and groups.

Anderson, E. C.
In prep. An efficient framework for Monte Carlo compuations on the coalescent to estimate Ne from temporally-spaced samples.

Anderson, E. C., and **K. K. Dunham**.
In prep. spip 1.0: program for simulating pedigrees and genetic data in age-structured populations.

Anderson, T. J., G. R. Cochrane, D. A. Roberts, H. Chezar, and G. Hatcher.
In prep. A systematic and real-time method for groundtruthing seafloor habitat maps: an example of habitat mapping in the Channel Islands National Marine Sanctuary using a sidescan and towed camera-sled survey.

Armsworth, P. R., C. V. Kappel, F. Micheli, and **E. P. Bjorkstedt**.
In prep. Working seascapes: the protection of endangered species and the conservation of biodiversity in marine ecosystems.

Barnett-Johnson, R. C., F. C. Ramos, **C. B. Grimes**, and **R. B. MacFarlane**.
In prep. Identifying the natal origin and migration history of adult salmon using Sr isotopes obtained by laser ablation MC-ICPMS.

Bjorkstedt, E. P.
In prep. Competition in common habitats: implications for the metapopulation dynamics of stage-structured species.

Bjorkstedt, E. P.
In prep. DARR (version 2.0.1.): updated software for analysis of stratified mark-recapture data.

Bjorkstedt, E. P.
In prep. Estimating population size in small populations using stratified mark-recapture techniques.

Bjorkstedt, E.
In prep. To swim or not to swim? Optimal strategies for pelagic life history and settlement of juvenile rockfish in a coastal upwelling system.

Bjorkstedt, E., and J. Roughgarden.
In prep. A method for detecting fronts with solo high-frequency (HF) radar, with application in a coastal upwelling region.

Black, B. A., G. W. Boehlert, and **M. M. Yoklavich**.
In review. Using tree-ring crossdating techniques to validate age in longlived fishes.

Boughton, D. A.
In prep. A practical method for estimating uncertainty about the absence of species.

Boughton, D. A., and **H. Fish**.
In prep. Current distribution of steelhead (*Oncorhynchus mykiss*) in coastal streams of southern California.

Day, G. R., **C. B. Grimes**, and D. A. DeVries.
In prep. Distribution, abundance, growth and mortality of striped anchovy, *Anchoa hepsetus*, along environmental gradients associated with the Mississippi River discharge plume.

Dick, E. J.
In prep. Beyond "lognormal vs. gamma": discrimination among error distributions for generalized linear models.

Goldwasser, L., **M. S. Mohr**, A. M. Grover, and M. L. Palmer-Zwahlen.
In prep. The Klamath ocean harvest model: supporting databases and analyses.

Grimes, C. B., and C. S. McNeil.
In prep. Diet and feeding ecology of striped anchovy, *Anchoa hepsetus*, along environmental gradients associated with the Mississippi River discharge plume.

Grimes, C. B., and D. A. DeVries.
In prep. Growth and mortality of Spanish mackerel larvae along environmental gradients associated with the Mississippi River discharge plume.

Hankin, D. G., and **M. S. Mohr**.
In prep. Two-phase survey designs for estimation of fish abundance in small streams.

He, X., M. Mangel, and **A. MacCall**.
In prep. A one-tailed prior for steepness based on an evolutionary persistence principle.

Holloway, G., **D. Tomberlin**, and X. Irz.
In prep. Hierarchical analysis of production efficiency in a coastal trawl fishery.

Isely, J. J., **C. B. Grimes**, and A. W. David.
In prep. Identification of hatchery-reared and wild red drum, *Sciaenops ocellatus*, using discriminant analysis of otolith banding patterns.

Johnson, R. C., and **R. B. MacFarlane**.
In prep. Estuary use and growth history of juvenile Chinook salmon from the California Central Valley juvenile in the San Francisco Bay Estuary.

Johnson, R. C., **C. B. Grimes**, and **C. F. Royer**.
In prep. Discrimination of hatchery and wild chinook salmon (*Onchorynchus tshawysha*) in the California Central Valley using otolith microstructure.

Kahn, R. G., **D. E. Pearson**, and **E. J. Dick**.
Submitted. Comparison of standard length, fork length, and total length for measuring fish.

Love, M. S., and **M. M. Yoklavich**.
In review. Fishes on deep rock habitats. In: L. Allen, M. Horn, and D. Pondella (eds.), Ecology of California marine fishes. University of California Press.

MacCall, A.
In prep. Worldwide sardine and anchovy fluctuations: an historical review from the perspective of California, and a new hypothesis of their origin.

MacFarlane, R. B., **S. Ralston**, **C. Royer**, and **E. C. Norton**.
In review. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) growth on the central California coast during the 1998 El Nino and 1999 La Nina.

Mills, K. L., **S. Ralston**, **T. Laidig**, and W. J. Sydeman.
In review. Functional response curves and the use of top predator diet as indicators of pelagic juvenile rockfish (*Sebastes* spp.) abundance in the California Current system.

Newman, K. B., and **S. T. Lindley**.
In prep. Modeling the population dynamics of winter-run chinook salmon.

Newman, K., and **S. T. Lindley**.
In prep. Hidden process models for salmon population dynamics.

Newman, K., S. Buckland, C. Fernandez, **S. T. Lindley**, and L. Thomas.
In review. Hidden process models for animal population dynamics.

Norton, E. C., and **R. B. MacFarlane**.
In prep. Feeding habits of juvenile salmon (*Onchorhynchus tshawytscha*) in the San Francisco Estuary.

Norton, E. C., and **R. B. MacFarlane**.
In prep. Interannual variability of juvenile shortbelly rockfish lipids in relation to environmental conditions off the California coast.

O'Hanley, J., and **D. Tomberlin**.
In review. A nonlinear model for the optimal removal of fish passage barriers.

Ralston, S., W. H. Lenarz, and D. P. Woodbury.
In prep. Long-term variability in year-class strength of northern California rockfishes (*Sebastes* spp.) in relation to the larval ocean environment and young-of-the-year growth.

Reynolds, J. A., **S. Ralston**, and T. M. Powell.
In prep. Temporal stability of the association between widow rockfish (*Sebastes entomelas*) and bottom depth.

Sakuma, K. M., C. A. Taylor, and W. Watson.
In review. Pigment variability in larval shortbelly rockfish, *Sebastes jordani*, off central California.

Sakuma, K. M., **S. Ralston**, and D. A. Roberts.
In prep. Temporal patterns of larval Pacific hake (*Merluccius productus*) and rockfish (*Sebastes* spp.) at a single fixed station off central California.

Stephens, A., and **A. MacCall**.
In prep. A multispecies approach to subsetting logbook data for purposes of estimating CPUE.

Thomson, C., and D. Cai.
In prep. Modeling angler behavior in Pacific coast recreational fisheries.

Tissot, B. N., **M. M. Yoklavich**, M. S. Love, K. York, and **M. Amend**.
In prep. Structure-forming invertebrates as components of benthic habitat on deep banks off Southern California.

Tomberlin, D., and V. Bosetti.
In prep. Solving real options models of fisheries investment when salvage value is difficult to estimate.

Wahle, C., D. Brumbaugh, **M. Yoklavich**, M. Carr, et al.
In prep. Phased establishment of a network of marine protected areas: matching policy expectations with ecological reality.

Wells, B. K., **C. Grimes**, J. C. Field, and C. S. Reiss.
In review. Covariation between the average lengths of mature coho and chinook salmon and the ocean environment.

Yoklavich, M. [and others?].
In review. Our living oceans: habitat. NOAA National Marine Fisheries Service.

LIST OF PUBLICATIONS BY YEAR

IN PRESS

Anderson, T. J., **M. M. Yoklavich**, and S. L. Eittreim.
In press. Linking fine-scale groundfish distributions with large-scale seafloor maps: issues and challenges of combining biological and geological data. In: Proceedings of Symposium on the Effects of Fishing on Benthic Habitats. AFS Symposium.

Dalton, M. G., and **S. Ralston**.
In press. The California rockfish conservation area and groundfish trawlers at Moss Landing Harbor. Journal of Marine Resource Economics.

Gieger, S. P., J. J. Tores, and **C. B. Grimes**.
In press. Measures of physiological condition in larval anchovies, *Anchoa hepsetus*, collected in the discharge plume of the Mississippi River during the flood of 1993. Marine Ecology Progress Series.

Hayes, S. A., **M. H. Bond**, **C. V. Hanson**, and **R. B. MacFarlane**.
In press. Interactions between endangered wild and hatchery salmonids: can the pitfalls of artificial propagation be avoided in small coastal streams? Journal of Fish Biology.

Hobson, E. S.
In press. Evolution of California marine teleost fishes. In: L. Allen, M. Horn, and D. Pondella (eds.), Ecology of California marine fishes.

Lessa, E. P., G. Wlasiuk, and **J. C. Garza**.
In press. Dynamics of genetic differentiation in the Rio Negro tuco-tuco (*Ctenomys rionegrensis*) at the local and geographical scales. In: Mammalian diversification: from population genetics to biogeography.

MacCall, A. D., H. Batchelder, J. King, D. Mackas, N. Mantua, G. A. McFarlane, I. Perry, J. F. Schweigert, and F. Schwing.
In press. Recent ecosystem changes in the California Current System. In: Report of the PICES study group on fisheries and ecosystem responses to recent regime shifts.

Pastor, T., **J. C. Garza**, P. Allen, W. Amos, and A. Aguilar.
In press. Low genetic variability in the highly endangered Mediterranean monk seal. Journal of Heredity.

Tomberlin, D.

In press. The allocation problem in habitat restoration. In: Proceedings of the NMFS Habitat Restoration Cost workshop.

PUBLICATIONS - 2004

Allen, S., R. Carlson, and **C. Thomson** (eds.).
2004. Proceedings of the Salmon Habitat Restoration Cost Workshop. Pacific States Marine Fisheries Commission, Portland, Oregon.

Berkeley, S. A., C. Chapman, and **S. M. Sogard**.
2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85(5):1258-1264.

Garza, J. C., **L. Gilbert-Horvath**, **J. Anderson**, **T. Williams**, **B. Spence**, and **H. Fish**.
2004. Population structure and history of steelhead trout in California. In: J. Irvine, et al. (eds.), Workshop on Application of Stock Identification in Defining Marine Distribution and Migration of Salmon (Honolulu, Hawaii, USA, November 1-2, 2003). North Pacific Anadromous Fish Commission, Technical Report 5:129-131.

Klamath River Technical Advisory Team.
2004. Klamath River fall chinook age-specific escapement, 2003 run. Klamath Fishery Management Council, Yreka, California. 16 p.

Klamath River Technical Advisory Team.
2004. Ocean abundance projections and prospective harvest levels for Klamath River fall chinook, 2004 season. Klamath Fishery Management Council, Yreka, California. 30 p.

Laidig, T. E., **K. M. Sakuma**, and J. A. Stannard.
2004. Description and growth of larval and pelagic juvenile pygmy rockfish (*Sebastes wilsoni*) (family Sebastidae). Fishery Bulletin 102(3):452-463.

Lindley, S. T., **R. Schick**, B. P. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, **R. B. MacFarlane**, C. Swanson, and J. G. Williams.
2004. Population structure of threatened and endangered chinook salmon ESUs in California's Central Valley basin. NOAA Technical Memorandum NMFS-SWFSC-370. 56 p.

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